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WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN, MASSACHUSETTS

DESIGN MEMORANDUM NO. 1

HYDROLOGY AND TIDAL HYDRAULICS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

MAY 1971

DAEN-CWE-B (NEDED-E, 21 May 71) 3rd Ind
SUBJECT: Charles River Locks and Dam, Charles River Basin, Massachusetts, Design Memorandum No. 1, Hydrology and Tidal Hydraulics

DA, Office of the Chief of Engineers, Washington, D.C. 20314 23 November 1971

TO: Division Engineer, New England, ATTN: NEDED-E

The information furnished and actions proposed in the 2nd Indorsement are satisfactory.

FOR THE CHIEF OF ENGINEERS:

W. D. Phillips
for JOSEPH M. CALDWELL
Chief, Engineering Division
Directorate of Civil Works

NEDED-E (21 May 71) 2nd Ind
SUBJECT: Charles River Locks and Dam, Charles River Basin, Massachusetts, Design Memorandum No. 1, Hydrology and Tidal Hydraulics

DA, NED, CE, Waltham, Mass. 02154 23 September 1971

TO: Chief of Engineers, ATTN: ENGCW-EZ

Comments with reference to paragraph 2 in the 1st Indorsement follow:

Subparagraph a.

Information noted will be included in the General Design Memorandum. The reference to "300 acres" to be added to the water surface area as indicated in this subparagraph is in error and should be changed to read "30 acres".

Subparagraph b.

The design of the lock sector gates will be checked with the latest model test data and the results will be included in Design Memorandum No. 7, Navigation Locks and Facilities.

FOR THE DIVISION ENGINEER:

John Wm. Leslie

JOHN Wm. LESLIE
Chief, Engineering Division

ENGCW-EZ (NEDED-E, 21 May 1971) 1st Ind
SUBJECT: Charles River Locks and Dam, Charles River Basin, Massachusetts, Design Memorandum No. 1, Hydrology and Tidal Hydraulics

DA, Office of the Chief of Engineers, Washington, D.C. 20314 2 August 1971

TO: Division Engineer, New England, ATTN: NEDED-E

1. Approved, subject to the following comments.

2. Section L.

a. Paragraphs 2a and 2b. The General Design Memorandum should contain sufficient project formulation information to demonstrate that the selected top of dam elevation and pumping station capacity are appropriate.

b. Paragraph 2c. The design of the lock sector gates should be checked with the latest model test data from WES to insure satisfactory operation under reverse head.

FOR THE CHIEF OF ENGINEERS:

B J Blankinship

JOSEPH M. CALDWELL
Chief, Engineering Division
Civil Works Directorate

1 Incl
wd

ENGCW-EZ (NEDED-E, 21 May 1971) 1st Ind
SUBJECT: Charles River Locks and Dam, Charles River Basin, Massachusetts, Design Memorandum No. 1, Hydrology and Tidal Hydraulics

DA, Office of the Chief of Engineers, Washington, D.C. 20314 2 August 1971

TO: Division Engineer, New England, ATTN: NEDED-E

1. Approved, subject to the following comments.

2. Section L.

a. *Paragraphs 2a and 2b.* The General Design Memorandum should contain sufficient project formulation information to demonstrate that the selected top of dam elevation and pumping station capacity are appropriate.

b. Paragraph 2c. The design of the lock sector gates should be checked with the latest model test data from WES to insure satisfactory operation under reverse head.

FOR THE CHIEF OF ENGINEERS:

1 Incl
wd

B J Blanchard
JOSEPH M. CALDWELL
Chief, Engineering Division
Civil Works Directorate

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

IN REPLY REFER TO:

NEDED-E 21 May 1971

SUBJECT: Charles River Locks and Dam, Charles River Basin, Massachusetts, Design Memorandum No. 1, Hydrology and Tidal Hydraulics

Chief of Engineers
ATTN: ENGCW-E

1. In accordance with ER 1110-2-1150, there is submitted for review and approval Design Memorandum No. 1, Hydrology and Tidal Hydraulics, for the Charles River Locks and Dam Project.

2. The Design Memorandum was prepared by Charles A. Maguire & Associates, Consulting Engineers, Boston, Massachusetts, under contract to the New England Division. The basic planning and engineering studies previously accomplished for the Metropolitan District Commission, Commonwealth of Massachusetts, have been revised to meet the Corps' criteria. The report was reviewed by this Division.

3. All elevations shown in this Memorandum are based on M. D. C. (Metropolitan District Commission) Datum which is 105.65 feet below mean sea level.

FOR THE DIVISION ENGINEER:

John Wm Leslie
JOHN Wm. LESLIE
Chief, Engineering Division

Incl (7 cys)
as

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN
MASSACHUSETTS

Design Memorandum Index

No.	Title	Anticipated Submission Date	Date Submitted	Date Approved
1	Hydrology and Tidal Hydraulics	May 1971	21 May 1971	
2	General Design, Site Geology and Relocations	July 1971		
3	Concrete Materials	Feb 1971	19 Feb 1971	29 Mar 1971
4	Embankments and Foundations	Jul 1971		
5	Pumping Station	Aug 1971		
6	Vehicular Viaduct	Aug 1971		
7	Navigation Locks and Facilities	Sep 1971		

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN
MASSACHUSETTS
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND TIDAL HYDRAULICS

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CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS

Purposes	Flood Control, Navigation, Recreation, Transportation and Conservation
Location	Boston, on the Charles River 2,250 feet downstream of the present Charles River Dam

Drainage Areas

Total Watershed	307 square miles
Lower Charles River above existing dam	56 square miles
Lower Charles River above proposed dam	58 square miles

307
56
251

Surface Areas

Datum Relations	M.D.C. Base is 105.65 feet below mean sea level (MSL), U.S.C. & G.S. Datum of 1929. [105.65 M.D.C. = 0.0 MSL U.S.C. & G.S. (1929)]
Charles River Basin at Elevation 108 M.D.C.	
Existing Basin	675 acres
Proposed Basin	705 acres

Existing Charles River Dam and Basin

Basin area at Elevation 108.0 M.D.C.	675 acres
Sluice Gates	8 @ 7.5 x 10', each
Large boatlock	
Width	45 feet
Length	350 feet
Depth at tidal sill at mean low water	17 feet
Small boatlock	Abandoned

Elevations	Feet M.D.C. Base
Top of dam	121.0
Sill of sluice gates	97.75
Basin sill of large boat lock	86.9
Tidal sill of large boatlock	83.6
Normal basin level	108.0
Basin level (Prelowering) (M.D.C. base)	107.0
Desired maximum basin level (M.D.C. base)	110.0
October 1962 basin level	109.6
September 1954 basin level	110.5
March 1968 basin level	110.8
August 1955 basin level (Maximum recorded)	112.5

Proposed Charles River Locks and Dam

Dam

Type	Earthfill, rock slope protection
Top elevation	118.0 feet M.D.C. Base
Maximum height	36' above river bed

Navigation Locks

Commercial and recreational	One
Length	300 feet
Width	40 feet
Basin sill elevation	91.0 feet M.D.C. Base
Tidal sill elevation	86.0 feet M.D.C. Base
Recreation only	Two
Length	200 feet
Width	25 feet
Basin sill elevation	100.0 feet M.D.C. Base
Tidal sill elevation	94.0 feet M.D.C. Base

Pumping Station

Structure	Reinforced concrete 145 x 184 feet
Pumps	6 @ 1400 c.f.s. = 8400 c.f.s.
Intake sill elevation	82.5 feet M.D.C. Base

Fishway

Fishway channel width	4 feet
Fish lock channel width	6 feet
Pump	50 c.f.s.
Fishway sluice gate	2(4x4), 1(4x10) feet
Fish lock sluice gate	6 x 6 feet
Fish lock floor elevation	103.0 feet M.D.C. Base

Sluices

Low sluice	
Size	8 x 10 feet
Sill elevation	87.0 feet M.D.C. Base
High sluice	
Size	8 x 10 feet
Sill elevation	95.5 feet M.D.C. Base

Tides Boston Harbor (Elevations, feet, M.D.C. Base)

Highest tide of record April 14, 1851	115.7
Mean high water	110.2
Mean low water	100.8
Highest tide, modern record Dec. 29, 1959	115.0
Design tide elevations	
High	113.0
Low	102.5

105.65
9.35

Floods

Flood of record Aug. 1955	13,400 c.f.s.
Standard Project Flood	20,000 c.f.s.
Design Project Flood	15,500 c.f.s.

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN
MASSACHUSETTS
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND TIDAL HYDRAULICS

A. GENERAL

The purpose of this memorandum is to present hydrologic data that is pertinent to the design of a new dam for the Charles River Basin. It describes the watershed of the Charles River, the flood problems above the existing Metropolitan District Commission Dam, the analysis of historical floods in the watershed and the development of synthetic floods for the lower watershed. It also includes sections on climatology, runoff and tidal hydraulics.

B. WATERSHED DESCRIPTION

1. Charles River Watershed

a. Location - The Charles River Watershed is located in the Eastern part of Massachusetts and extends primarily Southwesterly from its outlet into Boston inner harbor through Suffolk, Norfolk, Middlesex, and Worcester Counties. It is bordered by the watersheds of the Mystic, Merrimack, Blackstone, Taunton, and Neponset Rivers. The watershed is about 307 square miles in area and consists of a portion of the highly developed Metropolitan Boston area plus a less developed but rapidly growing suburban and rural area and is shown on Plates 1 and 2.

b. Physical Features - The watershed extends in a southwesterly-northeasterly direction and is about 31 miles in length. It has roughly an hourglass shape with widths of 15 miles more or less at the bulges to about 6 miles at the waist. Elevations vary from 530 feet above mean sea level in the upper highlands in Hopkinton to less than 10 feet above mean sea level along the lower 8-1/2 miles of the river.

The drainage area has 33 lakes and ponds with a total surface area of over 2,500 acres. This figure does not include the ponded areas along the river itself or the widespread swamplands. Because of the combination of moderate slopes, pervious soils, ponds and lakes, extensive swamplands and diversions, the upper portion is unusually slow in responding to heavy rains.

2. Charles River

a. Description - The Charles River rises at Echo Lake in the Town of Hopkinton about 25 miles southwest of the City of Boston at an elevation of approximately 347 feet above mean sea level. The river flows in a generally northeasterly course, winding back and forth through extensive swamplands and passing through many heavily built-up areas until it reaches the Charles River Basin at Watertown. From this point it flows to tidewater at the existing Charles River Dam. Along its course it flows by the towns of Milford, West Medfield, Medfield, South Natick, Needham, (Charles River Village) and Dedham, and the cities of Waltham, Watertown, Newton, Boston, and Cambridge.

The total length of the river is less than 80 miles and the fall from Echo Lake at the headwaters to the Charles River Basin is about 345 feet. In the lower 33 miles the drop is 98 feet. There are approximately 22 dams located on the river, some of which are still used for impounding mill process water.

3. Lower Charles River

a. Location - The lower Charles River watershed is considered, for hydrologic reasons, to extend from the Moody Street Dam in Waltham northeasterly for about 12-1/2 miles to its mouth at tidewater below the existing Charles River Dam. A plan of the watershed is shown on Plate 2.

b. Description - The Lower Charles River Watershed covers an area of approximately 56 square miles behind the existing dam and an additional 2 square miles between the existing and proposed dams. Muddy River, Stony Brook and Beaver Brook are the major tributaries which enter the main river. Together they drain about 60 percent of the total watershed for the Lower Charles River. Below Watertown the drainage area comprises a highly concentrated urban and suburban type development with extensive impervious areas in the form of roofs, parking areas and streets. A highly developed sewer system combines with numerous tributary inflows to discharge into the Basin. These conditions are conducive to a high degree of runoff.

c. Tributaries

(1) Beaver Brook - Beaver Brook rises in the Town of Lexington and flows in a general southerly direction for 6 miles to its confluence with the Charles River in Waltham. Along the last mile of its length it is inclosed in a conduit. Beaver Brook has a fall of 190 feet and together with its two principal tributaries, Clematis and Chester Brooks, has a total drainage area of 11.2 square miles.

(2) Muddy River and Back Bay Fens - Muddy River rises in Jamaica Pond, in the west-central part of Boston, at an elevation of approximately 165.6 feet MDC base (or) 60 feet above mean sea level and flows northerly about 2 miles through a series of small ponds, conduits and channels discharging into the Back Bay Fens through a conduit under Park Drive. At this location the drainage area is 6.1 square miles. Muddy River has a drop of 56 feet in the first 2,000 feet below Jamaica Pond. The remaining length of the river is very sluggish and during normal flows remains at a nearly constant level of 108.6 feet MDC. The dry weather flow of Muddy River continues northerly about 2,000 feet in a conduit under Brookline Avenue and Deerfield Street and empties into the Charles River Basin about 3 miles above the Charles River Dam.

The Muddy River in Back Bay Fens flows through a series of conduits and open channels with landscaped banks for a distance of about 1.2 miles. The flow continues for nearly 0.4 mile mainly through conduits and under numerous bridges to the Charles River Basin at a point upstream of the Massachusetts Avenue bridge. The Fens, in the backwater of the Charles River Basin, has a local drainage area of 1.1 square miles.

About 1 mile above the Fens outlet at the Basin, two gatehouses control the discharge of storm overflow from Stony Brook into the Fens. Stony Brook rises in Turtle Pond in Stony Brook Reservation and flows in a general northerly direction for a distance of approximately 7 miles. This stream follows the old course of Stony Brook and has a total drainage area of 13.9 square miles. Except for a length of one mile at its upper end, the brook is now inclosed in a conduit. The low flows of the Stony Brook Conduit are discharged through the so-called "Foul Flow Channels" to the Boston Marginal Conduit. This conduit follows the south bank of the Basin and empties into the tidal portion of the Charles River just downstream of the existing Charles River Dam.

d. Elevation Comparisons - There are two elevation datums used in the area. They are the Metropolitan District Commission Datum (M.D.C.) and the United States Coast and Geodetic Survey Means Sea Level Datum of 1929 (M.S.L.). The M.D.C. Datum is 105.65 feet below 0.0 M.S.L. (105.65 feet M.D.C. = 0.0 feet M.S.L.).

e. Existing Charles River Basin

(1) Description - The Charles River Basin is that portion of the river between the existing Metropolitan District Commission Dam at Leverett Street and the Watertown Dam. Most of this reach was a tidal estuary until the construction of the Metropolitan Commission Dam in 1910.

The Dam was constructed to create a fresh water pool known as the Charles River Basin. The primary objectives of the project were to eliminate the extensive mud flats and noxious odor at low tide, to protect the low areas in Boston and Cambridge from high tides, and to maintain a more or less constant basin level and to stabilize the groundwater table in the adjacent areas.

So-called marginal conduits were also constructed along both the Boston and Cambridge banks of the River to reduce the pollution in the Basin. The lands adjacent to the Basin and the Basin itself become both a land and water park of great benefit to the community.

(2) Physical Features - The Charles River Dam is a low earth fill structure connecting Boston and Cambridge along Leverett Street, one of the most heavily traveled roads in the metropolis. The Dam, with top elevation 121.0 feet M.D.C. is 1,200 feet long and from 100 to 500 feet in width with vertical walls of cut granite blocks. A main feature of the Dam is the navigation lock which is 45 feet wide with a clear distance of 350 feet between lock gates. Elevation of the upper gate sill is 86.9 feet M.D.C. The lock gates are horizontal beam-type, operating on a track. The lock gates cannot be operated with any appreciable head against them and therefore are opened or closed only when the water level is the same on both sides of the gate. The hydraulic facilities also include a sluiceway and 8 sluice gates, each 7 x 10.5 feet which are used to control the Basin level and a small boat lock. The small boat lock is no longer in use and has been sealed. Plate 3 shows the Dam and locks.

The normal Basin elevation of 2.4 feet MSL is equivalent to 108.0 feet M.D.C. Datum. This elevation, selected to give the maximum benefit to upstream areas, is lower than the mean high tide. Therefore, for a period of 4 or more hours during each tide cycle, the sluice gates cannot be used for sluicing and are closed to prevent salt water inflow from the harbor. With normal runoff or moderate floods there is sufficient storage in the Basin so that closure of sluice gates during this period results in only a minor rise in the Basin level.

Upstream of the Dam the Basin has a maximum width of about 2,000 feet, which gradually decreases to less than 400 feet at the Boston University Bridge about 3 miles upstream of the Dam. Above this location the Basin resembles a river with banks generally from 300 to 500 feet apart. At the Watertown Dam, about 8-1/2 miles upstream of the Charles River Dam, the width is further reduced to 150 feet. The Basin depth generally varies from 3 feet in Watertown to a maximum depth of approximately 30 feet in the lower reaches.

The original Basin produced a water surface area of 776 acres at normal pool level. Since 1908 the Basin has decreased 101 acres with the construction of Storrow Drive and recreational areas, and at present the water surface area is 675 acres.

The shoreline involves a length of approximately 20 miles with adjoining areas generally low, particularly in Back Bay and parts of Cambridge. There are extensive areas not more than 7 feet above the normal Basin level and a few areas only 5 feet above normal Basin levels.

C. CLIMATOLOGY

1. General - The Charles River Watershed is subjected to the four distinct seasons that are typical of the New England area. The climate is changeable and is subjected to frequent but generally short periods of precipitation. The area lies in the path of the prevailing westerlies and the cyclonic disturbances that cross the country from the west and southwest. It is also exposed to coastal storms that move up the Atlantic Seaboard, some of which are of tropical origin. In late summer and autumn months these storms occasionally attain hurricane intensity with high winds, heavy rainfall and abnormally high tides. Precipitation and temperature for Blue Hills, Boston and Chestnut Hill, Massachusetts, are tabulated in Tables 1 through 3.

2. Temperature - The average annual temperature of the lower Charles River Watershed is about 50°F. The coldest months are January and February with mean temperatures of about 29°F. and lows close to -20°F. July and August are the warmest months with mean temperatures of about 72°F. and occasional highs over 100°F. Temperatures in the upper watershed are slightly lower due to the higher elevations.

3. Precipitation - The average annual precipitation of the lower Charles River Watershed is about 43 inches which is rather evenly distributed throughout the year. The heaviest precipitation recorded at the three stations investigated was measured at Blue Hills and was just under 19 inches for the month of August 1955. The heaviest 24 hour rainfall was just under 10 inches and also occurred in August of 1955.

4. Snowfall - The annual snowfall over the lower watershed varies from about 42 inches at Boston on the coast to 60 inches at the Blue Hill Observatory, 640' above mean sea level. Snow cover reaches a maximum depth in early March with the water content often exceeding 2 inches. Mean monthly snowfall for Boston and Blue Hills, Massachusetts, is tabulated in Table 4.

TABLE 1

MONTHLY TEMPERATURES AND PRECIPITATION

BOSTON, MASSACHUSETTS

	Temperature 98 Years of Record			Precipitation 99 Years of Record		
Month	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	28.8	72	-13	3.60	9.54	.89
February	29.1	68	-18	3.38	7.08	.45
March	36.8	86	- 8	3.86	11.00	T
April	46.9	91	11	3.58	9.14	.93
May	57.7	97	31	3.24	13.38	.25
June	66.9	100	41	3.15	9.13	.27
July	72.5	104	50	3.17	11.69	.52
August	70.6	101	46	3.61	17.09	.39
September	63.9	102	34	3.19	10.94	.21
October	54.1	90	25	3.28	8.84	.06
November	43.3	83	-2	3.87	11.03	.59
December	32.5	69	-17	3.61	9.74	.66
ANNUAL	50.3	104	-18	41.47		

TABLE 2

MONTHLY TEMPERATURE AND PRECIPITATION

CHESTNUT HILL, MASSACHUSETTS

Month	Temperature 81 Years of Record			Precipitation 94 Years of Record		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	28.2	70	-17	4.02	9.95	1.64
February	28.2	68	-19	3.78	8.74	0.77
March	36.5	85	- 3	3.98	8.78	T
April	47.5	90	9	3.80	9.19	0.75
May	58.4	96	26	3.35	13.12	0.43
June	67.1	100	35	3.34	9.80	0.20
July	72.5	106	41	3.45	9.73	0.35
August	69.5	100	40	3.76	17.57	0.28
September	63.8	100	30	3.61	11.56	0.35
October	53.5	91	19	3.52	9.62	0.12
November	42.7	83	6	4.01	8.29	0.92
December	31.4	68	-14	3.65	8.31	0.72
ANNUAL	49.9	106	-19	44.27	63.10	29.44

TABLE 3

MONTHLY TEMPERATURE AND PRECIPITATION

BLUE HILLS, MASSACHUSETTS

	Temperature 135 Years of Record			Precipitation 85 Years of Record		
Month	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	25.0	68	-16	4.11	10.97	.89
February	25.5	67	-21	3.94	9.32	1.04
March	33.4	85	- 5	4.31	10.96	.06
April	43.9	89	6	3.87	8.71	.92
May	54.9	93	27	3.56	9.16	.50
June	63.8	99	36	3.44	10.78	.53
July	69.4	99	46	3.57	11.67	.13
August	67.5	101	39	4.04	18.78	1.05
September	60.7	99	28	3.95	11.04	.45
October	50.6	88	21	3.75	10.84	.22
November	39.6	81	5	4.23	9.29	.62
December	28.5	68	-19	4.19	12.60	.92
ANNUAL	46.9	101	-21	46.96		

TABLE 4

MEAN MONTHLY SNOWFALL
(Depth in Inches)

Boston, Massachusetts
Elevation 15 Feet msl
34 Years of Record

Month	Snowfall
January	12.5
February	12.2
March	8.1
April	0.7
May	T
June	0
July	0
August	0
September	0
October	T
November	1.2
December	7.5
ANNUAL	42.2

Blue Hills, Massachusetts
Elevation 640 Feet msl
83 Years of Record

Month	Snowfall
January	15.7
February	16.9
March	11.8
April	3.1
May	0.1
June	0
July	0
August	0
September	0
October	0.2
November	2.6
December	10.6
ANNUAL	61.0

5. Storms - The Charles River Watershed is subject to three general types of storm that may be classified as continental, thunderstorm, and hurricane. The rapidly moving continental or cyclonic storms that cross the basin from the west or southwest produce frequent periods of rainfall but are not extremely severe. Continental storms are apt to be more critical when they are of the stationary frontal type which may produce appreciable rainfall over a given area on several successive days. Thunderstorms may be of the frontal type associated with continental storms or of the local type and on a small drainage basin such as the Lower Charles Basin, can produce high rainfall intensities. The most severe storms in the area have been of the hurricane type of tropical origin that move up the eastern seaboard. They are most likely to occur during the late summer and autumn months.

There have been five storms in the last thirty-five years over the Charles River Watershed that have produced notable floods. They occurred in March 1936, July 1938, September 1954, August 1955, and recently in March 1968. The runoff from the hurricane "Diane" storm of August 1955 produced floods in much of Southern New England. The rains fell on ground that had been previously saturated by the rainfall from hurricane "Connie" which occurred one week earlier. Rainfall amounts for the period from the 17th through the 19th ranged from 10" to 15" over the watershed as shown on Plate 4.

D. RUNOFF

Stream Flow Data - The U.S. Geological Survey has maintained and published records for four stream gauging stations in the Charles River Watershed. In addition, they have published information on twenty-five miscellaneous sites and thirty-one low flow partial record stations established in 1968. Stream flow records at the four gauging stations are summarized in Table 5. There are several diversions along the watershed with the major one at Mother Brook in Dedham, Massachusetts, where the flows are diverted to the Neponset River through Dedham and Hyde Park. The Mother Brook gauge is located 0.4 mile downstream from the point of diversion from the Charles River. Gauge locations are shown on Plate 2. See Table 5.

TABLE 5

STREAMFLOW RECORDS

Location of Gaging Station	Drainage Area (sq. mi.)	Period of Record	Discharge (cfs) Mean	Maximum	Minimum Daily
Charles River at Charles River Village	184	1937-1969	292**	3,220	0.9
Mother Brook at Dedham	-	1931-1969	77	1,040	0
Charles River at Wellesley	211	1959-1969	312**	2,400	1.0
Charles River at Waltham	227*	1931-1969	368**	2,620	0.2

* Excludes 23.6 square miles drained by Stony Brook

** Adjusted for diversions at Mother Brook and municipal water supplies

E. FLOODS OF RECORD

1. General - Major floods on the Charles River can occur during any season of the year. Early spring rains combined with melting snow and frozen ground can result in floods similar to the ones of March 1936 and March 1968. Heavy rains during summer can cause runoff of the magnitude of the flood of July 1938 and hurricanes with their often torrential precipitation can cause flows similar to the August 1955 flood of record on the basin.

2. Historic Floods - Records of floods on the Charles River Watershed before the turn of the century are meager. From available information the greatest flood prior to 1900 occurred in February of 1886 when an estimated peak flow of 3,280 c.f.s. was experienced at Waltham. Other floods worth noting took place in 1807 and 1818.

3. Recent Floods

a. General - Five floods of major proportions have occurred on the Charles River in recent years: March 1936, July 1938, September 1954, August 1955 and March 1968. A brief description of each is given in the following paragraphs:

b. March 1936 flood - This flood, marked by two distinct peaks spaced about 6 days apart, resulted from a combination of runoff from melting snow and heavy rainfall from two major storms over the watershed. Rainfall amounts for the combined storms ranged from 4.5 inches in the lower watershed to more than 7 inches in the upper areas. On the Charles River at Charles River Village a peak discharge of 3,170 c.f.s. was computed from readings on the dam upstream. The March 1936 flood produced a maximum Basin elevation of 109.3 feet M.D.C. or 1.3 feet above normal.

c. July 1938 flood - During a 7-day period from 18 to 24 July, torrential rains fell throughout the Charles River Watershed resulting in near record flood levels along the main stream. A total of 9.2 inches of rainfall was measured at Brookline, Massachusetts. In the upper portion of the watershed at Milford, 12.3 inches of rain was recorded. Rainfall amounts in the lower watershed ranged from 4.0 inches at Boston to 7.7 inches at Framingham. A peak discharge of 3,110 c.f.s. was recorded at the Charles River Village gauge. The July 1938 flood resulted in the basin level rising to approximately 1 foot above normal.

d. September 1954 flood - The storm which accompanied hurricane "Carol" on 11-12 September 1954 produced the third highest stage in the Charles River Basin. An elevation of 110.55 feet M.D.C. was recorded at the Charles River Dam. A total storm rainfall of 6.32 inches was measured by the U.S. Weather Bureau at Boston. The maximum tide associated with hurricane "Carol" was 112.0 feet M.D.C.

e. August 1955 flood - This flood, one of the greatest of record on the Charles River, resulted from record rainfall accompaning hurricane "Diane" falling on a watershed saturated one week earlier by hurricane "Connie". Hurricane "Connie", 11-15 August, caused rainfall varying from 4 to 6 inches over southern New England and ended a period of drought. A week later, on 17-20 August, hurricane "Diane" brought rainfall from 16 to 20 inches over Massachusetts. Rainfall totals for hurricane "Diane" at Boston and Chestnut Hill were 12.5 and 13 inches, respectively. This storm also caused higher than normal tides in Boston Harbor. This condition combined with high local runoff resulting from very intense rainfall produced a record Basin elevation of 112.5 feet M.D.C., 4.5 feet above the normal level. Peak discharge at the Charles River Village gauge was 3,220 c.f.s. or about the same as the 1936 flood.

f. March 1968 flood - Heavy rainfall occurring over southern New England on 17-18 March resulted in the second largest flood of record in the lower reaches of the Charles River. The highest amounts of precipitation fell in the Blue Hills area just southwest of Boston with 7.7 inches measured. The Charles River Basin rose 2.85 feet above normal and inundated sections of Storrow Drive. This is the second highest rise in the Basin exceeded only by the 4.5 foot rise in August 1955. Peak discharge at the Charles River Village gauge was the same as the 1955 flood, 3,220 c.f.s.

F. FLOOD PROFILES

1. General - High water profiles on the Charles River were determined from field surveys after the floods of March 1936 and August 1955. Water surface profiles of the lower Charles River Watershed for these floods are shown on Plate 5.

2. Flood Problems in Charles River Basin - The flood problem in the Charles River Basin and surrounding low areas in Cambridge and the Back Bay section of Boston is caused by the loss of Basin control due to the high storm water runoff percentage from that small but highly developed portion of the watershed below Waltham. The flows from this area develop within a few hours after the beginning of heavy rainfall. Because the Basin level is 2.5' below mean high water in the harbor, the flows from storms must be stored from 4 to 6 hours during each high tide cycle. This storage can be readily accomplished during normal runoff and some minor floods, but runoff from major storms during the high tide cycle in addition to inadequate discharge capabilities, urban expansion and encroachments combine to produce progressively higher uncontrollable Basin elevations. Up until 1947 the Basin had never reached a level of 110.0 feet M.D.C. base, but since then it has gone over the 110.0 mark on several occasions with a high level of 112.5 on August 19, 1955.

G. ANALYSIS OF FLOODS

1. General

The design of the existing Charles River Basin and Dam facilities was based on the flood of February, 1886. The maximum rate of flow at Waltham for this flood did not occur until two or three days after maximum rainfall. The designers of the Basin estimated that the maximum rate of flow for the area below Waltham lagged a few hours after maximum rainfall.

The sluices and other openings in the Dam were originally designed to pass a flood flow of 5,700 c.f.s. with the normal Basin level maintained at elevation 108.0 feet M.D.C. It was estimated that with a discharge of 5,700 c.f.s. and a high tide level of 113.0 feet M.D.C. in the harbor, the Basin level would reach elevation 111.0 feet M.D.C.

An extreme flood discharge of 7,000 c.f.s. was also evaluated by the original engineers for the Basin. They estimated that with 7,000 c.f.s. discharging against a high tide elevation of 113.0 feet M.D.C. the Basin could rise to a maximum elevation of 113.4 feet M.D.C., remain at elevation 113.0 feet M.D.C. for four hours, and at elevation 111.0 feet M.D.C. for twenty-four hours. The conclusion was that the possibility of this situation ever occurring was remote, and even if it were to occur, it was thought that no serious damage would be done. As can be seen, the original engineers for the Basin realized even then, the possibility for extreme flooding, but considered the possibility remote. However, these engineers could not foresee the tremendous urban development of the area, and its ensuing effect on the runoff characteristics of the watershed.

2. Floods in the Basin

The major floods of record in the Basin have been analyzed to determine the hydrologic development of the floods and tributary components contributing to the crests. Pertinent features of the August 1955, October 1962 and March 1968 floods are shown on Plates 6 and 7. Basic data for this analysis include Basin elevations at the M.D.C. Charles River Dam, discharge records at the U.S.G.S. gauging station at Waltham and rainfall records at Cambridge and at Logan Airport in East Boston. These records are continuous throughout the several flood periods studied.

Records of concurrent harbor and Basin levels have been maintained at the MDC dam since its completion in 1910. These records also include operational data for the sluice and lock gates. There are 8 gravity sluice gates used to control the Basin level, each 7 x 10.5 feet and normally either closed or fully opened. Discharge through these gates depends on the differential head between the Basin and harbor. With the Basin at its normal elevation of 108.0 feet M.D.C. each gate can discharge about 700 c.f.s. with the harbor at MSL or lower. Upon advance warning of an approaching serious storm, the normal Basin elevation 108.0 feet M.D.C. is drawn down. Normally, the Basin is lowered to elevation 107.0 feet M.D.C. however, the Basin has been drawn down to as low as 106.5 feet M.D.C.

During the flood of August 1955, the Basin was drawn down below elevation 107.0 feet M.D.C. prior to peak discharge, but the Basin level rose quickly to a crest of elevation 112.5 feet M.D.C. The Basin crest coincided with peak flood and high tide in the harbor. If the Basin had been drawn down to elevation 105.7 feet M.D.C. prior to flood crest the Basin would have reached a crest of 112.2 feet M.D.C. or only 3 inches lower than the recorded crest elevation.

Total local inflow was computed by the conventional routing computation relating the change in Basin storage, as determined from the elevation levels, with the outflow through the sluice and lock gates. Local inflow to the Basin was determined by deducting the flow from Waltham and the rainfall directly on the Basin from the total inflow. Plate 8 shows the Basin capacity with the volume of the additional area between the existing and new dams added.

Peak flows from the upper watershed occur two or three days following an intense storm, but peak flow for the lower watershed occurs within two or three hours after the storm indicating the importance of local drainage to the Basin. The principal cause of the flood problems is considered to be the rapid runoff from the lower 56 square miles of the Charles River watershed above the existing dam.

The relative contributions from the lower and upper watersheds to the peak rate of inflow, and the volume of inflow producing the highest elevation in the Basin are shown in Table 6.

The progressive rise in flood stages in the Basin is attributed to:

a. The tremendous urban development in the lower Basin with the resultant tremendous increase in impervious area.
b. Extension and enlargement of storm drainage systems.
c. Reduction in natural storage areas by filling in of swamps, meadows and and Basin area.

3. Flow Pattern

During major floods, the discharge from the lower 56 square miles of the Charles River Watershed may contribute as much as 90% of the total flow to the Basin. This flow will probably peak 2 to 4 hours after the storm. Because the sluicing facilities at the existing Dam are totally dependent on the differential level of the Basin and tide in the Harbor for discharge, volume of storage in the Basin is critical, especially during the 4 to 5 hour period of the rising tide cycle when gravity discharge to the Harbor is not possible.

If a prolonged storm occurs which lasts several days, and the barometric pressure remains low, the low tide in the Harbor may remain at a relatively high level. Due to the total dependence of the discharge facilities on the differential water level between Basin and Harbor for discharge, a low tide that is several feet higher than normal can greatly reduce the discharge capacity of the sluicing facilities. Because discharge to the Harbor is not possible during a 4 to 5 hour period of the rising tide, and gravity sluicing is dependent on the tide level, control of outflow from the Basin to the Harbor is not possible.

TABLE 6

COMPARISON OF FLOOD FLOWS IN CHARLES RIVER BASIN

	Floods											
	1954		1955		1962		1968		PDS		SPF	
Item	CFS	%	CFS	%	CFS	%	CFS	%	CFS	%	CFS	%
Peak Inflow	9,600		13,400		6,000		4,800		15,500		20,000	
Upper Watershed*	900	9	1,300	10	600	10	1,800	38	2,100	13	2,700	13
Lower Watershed**	8,700	91	12,100	90	5,400	90	3,000	62	13,400	87	17,300	87
Maximum Basin Elevation												
MSL	4.9		6.9		4.0		5.2		7.2		7.9	
MDC	110.54		112.5		109.6		110.84		112.8		113.5	

* Upstream of USGS gaging station in Waltham, Drainage Area = 251 square miles
** Estimated at existing Charles River Dam = 56 square miles

H. FLOOD FREQUENCIES

Since completion of the M.D.C. dam in 1910, there have been numerous floods in which the Basin level has crested above its normal elevation of 108.0 feet M.D.C. Selected high stages in chronological order are as follows:

Year	Basin Elevation Feet MSL	Basin Elevation Feet M.D.C.
1911	3.48	109.10
1924	3.95	109.57
1931	4.20	109.82
1932	4.26	109.88
1938	4.15	109.77
1947	4.68	110.30
1949	4.44	110.30
1954	4.93	110.55
1955	6.88	112.50
1962	4.02	109.64
1968	5.23	110.85

I. STANDARD PROJECT FLOOD

1. General

A standard project flood (SPF) was developed for the lower Charles River Watershed to use as a guide for the design of the proposed improvements to the Charles River Basin. The standard project flood is based on the standard project storm being centered over the lower Watershed area. The total average rainfall for the standard project storm over the lower Watershed is calculated to be 13.1 inches. The flood hydrograph at the Dam is based on the local inflow hydrograph to the lower Basin plus a coincident flow from the upper Watershed at Waltham.

Because the sluicing facilities at the proposed Dam are partially dependent on the tide level of Boston Harbor for discharge, the standard project flood is based on volume of inflow going to storage in the Basin. Since pumping is to be provided at the new Dam, discharge to tide water during storms will always be possible. Pumping will help control the rising Basin level during the worst storm conditions, (coincidence of peak inflow and high tide in the harbor) until gravity sluicing along with pumping may be utilized to lower the Basin to a normal level.

2. Standard Project Storm

The standard project storm (SPS) for the lower Charles River Watershed was based on criteria as prescribed in Civil Engineering Bulletin No. 52-8. Comparison of the SPS with the August 1955 storm is shown in the tabulation below:

Time (Hours)	Precipitation 19 August 1955 (Inches)	SPS (Inches)
0	0	0
3	0.18	0.20
6	2.18	2.94
9	4.33	5.89
12	0.62	0.62
15	0.56	0.55
18	0.24	0.23
Totals	8.11	10.43

The isohyetetal pattern for the Standard Project Storm Study is shown on Plate 9.

3. Standard Project Flood

The local runoff for the August 1955 flood, as shown on Plate 6, was used as a guide for the establishment of the standard project flood. The total rainfall for the maximum 18 hour period amounted to 8.11 inches, of which 5.48 inches was the net local run off and 2.63 inches was loss. The rainfall excess as calculated for the standard project storm is 7.80 inches. Assuming the same loss (2.63 inches) as for the 19 August 1955 flood, the total rainfall for the SPS is 10.43 inches. In order to establish a relationship between the SPF and the August 1955 flood, the ration of rainfall excess (7.80 inches) for the SPF and the new runoff (5.48 inches) for the August 1955 flooded is calculated. This ratio is 1.4. The hydrograph for the SPF is established by multiplying the hourly local inflows for the August 1955 flood by 1.4, after making adjustments for the estimated recession from the previous day's runoff.

The hydrograph for the standard project flood was established using the following criteria:

(a) The flow from the Charles River at Waltham was assumed to reach a peak of 3000 CFS after 12 hours and to remain constant for the duration of the flood.

(b) The local inflow hydrograph is established as previously mentioned and is assumed to reach a peak flow of 17,300 CFS.

(c) The summation of Waltham inflow and peak inflow and peak local inflow produced a peak flow for the standard project flood of 20,000 CFS.

The peak flow for the SPF is assumed to occur simultaneously with high tide in Boston Harbor, similar to the design tide shown on Plate 11.

4. Project Design Flood

The project design flood as developed in the Metropolitan District

Commission "Report Upon Charles River Basin Control" is based on the inflow to the Basin experienced during the 1955 Hurricane "Diane" of 13,400 CFS with an allowance of 2100 CFS for future increased areas of impervious surfaces. The design storm hydrograph therefore has a peak flow of 15,500 CFS and is patterned after that developed for Hurricane "Diane".

A table of estimated rainfall frequencies for several of the hurricane storms was also developed in the Metropolitan District Commission Report and is shown in Table 7 following:

Table 7

Estimated Rainfall Frequency for Various Hours
of Duration of Certain Hurricane Storms

Storm	Date	Frequency-Years for Various Hours Duration of storm				
		1 Hr.	2 Hr.	3 Hrs.	4 Hrs.	5 Hr
Hurricane "Carol"	Aug. 31, 1954	2 yrs.	3 yrs.	3 yrs.	3 yrs.	3 yrs.
Hurricane "Edna"	Sept. 11, 1954	4 yrs.	8 yrs.	14 yrs.	20 yrs.	30 yrs.
Hurricane "Diane"	Aug. 18, 1955	4 yrs.	10 yrs.	7yrs	6yrs.	6 yrs.
Hurricane "Diane"	Aug. 19, 1955	7yrs	23yrs.	40yrs.	100 yrs.	100yrs.

It is apparent that the rainfall experienced during "Carol" and "Edna" can be expected to occur at relatively frequent intervals but "Diane" was most unusual for longer durations. Adequate facilities for the control of the Basin were therefore evaluated in the light of this type of storm.

J. TIDAL HYDRAULICS

1. Purpose

The purpose of this section of the memorandum is to determine the maximum tidal levels and the development of the frequency of flooding for the design of the Charles River Dam Project.

2. Description

The proposed Charles River Dam Project is located at the site of the old Warren Avenue bridge, approximately 0.6 of a mile upstream from the mouth of the Charles River at the Boston Harbor and approximately 0.4 of a mile downstream of the existing Charles River Dam.

3. Normal Tides

Two high and two low tides occur each lunar day in Boston Harbor. Spring tides have a greater range than the average, and occur during new moon and full moon when the tidal forces of the moon and the sun act in the same direction. Tidal Data for Boston Harbor are summarized in Table 8.

Table 8

NORMAL TIDES BOSTON HARBOR
(MDC BASE)

	Feet
Mean Tide Range	9.54
Spring Tide Range	13.0+
Mean High Water	110.2
Mean Low Water	100.8
Average Spring Tide High Water	110.9
Average Spring Tide Low Water	100.0
Max. High Water (On April 14, 1851) (including wind and Barometric effects)	115.7

4. Factors Influencing Tides

Besides the normal gravitational effects of the moon and sun, the tides are subject to meterological influences such as changes in atmospheric pressure and strong winds. A drop in barometric pressure of 1-inch of mercury results in approximately a 1-foot rise in the tide level. In addition, it is estimated that the tide level is constantly rising at the rate of approximately 0.6 foot per century. It is difficult to predict whether this rate will increase or decrease in the future and in view of the other design variables the rise will be relatively small over the life of the project.

5. Frequency of Tides

The maximum tide elevation vs. frequency curve for Boston Harbor is based on 200 years of record with elevations adjusted to 1970 levels for comparison purposes. The frequency curve is shown on Plate 12. The plotting positions of the points for the frequency curve as shown on Table 9 were calculated from the following formula:

$$P = \frac{100(M-0.5)}{Y}$$

Where

P= percent change of occurence in any one year.
M=number of event
Y= number of years of record.

6. Storm and Hurricane Influence

The prevailing storms for the Boston area are generally from the northeast. The northeasterly winds can sometimes cause the tide in Boston Harbor to rise 3 to 4 feet above predicted heights. The Minot's Ledge Tide of April 16, 1851, the maximum tide of record is 115.7 feet M.D.C. which is 5.5 feet above mean high water. Tide elevations 3.5 feet above mean high water occur about once a year.

The direction of hurricanes is generally from the southeast so that Cape Cod and the shape of the coastline near the Boston area affords protection against extreme hurricane tides or surges. However, Providence, Rhode Island, some 60 miles to southwest of Boston has experienced tides 12 to 15 feet above normal caused by hurricane winds being directed up funnel shaped Narragansett Bay toward Providence.

Hurricanes, as a whole, are very unpredictable and have been known to change their direction, and even to make a complete loop after hitting a high pressure area. If sustained hurricane force winds were to be directed to Boston Harbor from the east or northeast at high tide, the tide levels in Boston Harbor could be much higher than any recorded thus far. However, sustained hurricane force winds from the east or northeast are considered to be an extremely rare event.

7. Design Tidal Cycle

Shown on Plate II are the tide cycle for some hurricane storms which accompanied the peak Basin inflow. Also shown is the cycle for both the "Portland Tide" and the "Minot's Ledge Tide." The recommended design tide adopted for the project as shown on Plate II is the approximate mean of these tides. The cycle has a low of elevation 102.5 feet M.D.C., a high of 113.0 feet M.D.C.

8. Wind and Waves

The Charles River intersects Boston Inner Harbor at almost a right angle so the wave height at the site of the proposed Charles River Dam will be determined by a relatively short fetch of about 1300 yards. Boston Harbor itself is well sheltered from ocean waves. Since the shoaling of waves begins outside a harbor entrance and continues until they reach the beach area, the higher waves will be filtered out. Because of this the United States Naval Oceanographic Office in Washington, D.C., estimates that the average wave will be less than 3' in an area such as this. Independent analysis using methods outlined in Technical Report No. 4 U.S. Army Coastal Engineering Research Center and ETL 1110-2-8 give the following results:

Wind Velocity M.P.H.	Wave Height (Crest to Trough)
30	1.3'
40	1.8'
50	2.3'
60	2.9'
70	3.5'
80	4.1'
90	4.7'

Studies have shown that the maximum sustained wind velocities in the United States average 40 to 50 miles per hour for a period of one hour, but hurricanes can produce higher sustained velocities. Before the wind can pass up the Charles River Fetch, it must pass over the highland in East Boston and Winthrop. The combination of the high land and buildings will tend to reduce the velocity. Accordingly, a sustained wind velocity of 60 miles per hour has been considered as the design wind velocity. This velocity would produce a wave height of 2.9' if the reach had a clear opening to the new dam site. However, the Charlestown Bridge is just downstream of the dam site, and it constricts and blocks most of the opening with a series of pilings, piers and timber fenders. These should so dampen the waves that they should be almost insignificant at the dam. However, if the bridge was removed in the future, a 2.9' wave height could be expected. The wave run-up, under these conditions, on the riprap slope area of the dam would be between 1.5' and 2' vertical from still water elevation, depending on the grade of the slope and the direction of the slope. The wind tide effect for the fetch proper is negligible, and any effect of wind tide from the harbor is considered to be included in the design tidal cycle.

TABLE 9

MAXIMUM TIDE HEIGHTS
BOSTON, MASSACHUSETTS
(ADJUSTED TO 1970)

116 - 75 yr event
116.05 100 yr event
200 yrs 116.45
400 yrs. 116.8
1000 yr 117.2

Date of Occurrence	Maximum Tidal M.D.C.	Elevation M.S.L.	Percent Change of Occurrence In Any One Year	
			1931-1969	1723-1969
16 Apr. 1951	116.6	11.0		0.25
24 Feb. 1723	116.3	10.7		0.75
26 Dec. 1909	116.2	10.6		1.25
4 Dec. 1786	115.8	10.2		1.75
15 Dec. 1839	115.8	10.2		2.25
27 Dec. 1839	115.8	10.2		2.75
18 Apr. 1852	115.7	10.1		3.25
27 Nov. 1898	115.7	10.1		3.75
29 Dec. 1959	115.0	9.4	1.32	4.25
20 Oct. 1770	115.0	9.4		4.75
4 Mar. 1931	114.8	9.2	3.9	
21 Apr. 1940	114.8	9.2	6.5	
30 Nov. 1944	114.7	9.1	9.2	
20 Jan. 1961	114.5	8.9	11.9	
26 May 1967	114.5	8.9	14.5	
28 Jan. 1933	114.3	8.7	17.1	
17 Mar. 1956	114.3	8.7	19.8	
7 Apr. 1958	114.2	8.6	22.4	
12 Nov. 1947	114.0	8.4	25.1	
28 Feb. 1952	114.0	8.4	27.7	
31 Aug. 1954	114.0	8.4	30.3	
7 Mar. 1962	114.0	8.4	32.9	
20 Dec. 1945	113.9	8.3	39.6	
13 Apr. 1953	113.9	8.3	38.6	
6 Jan. 1931	113.9	8.3	41.9	
26 Apr. 1955	113.8	8.2	43.4	
2 Nov. 1963	113.8	8.2	46.1	
23 Oct. 1953	113.8	8.2	48.8	
2 Apr. 1939	113.8	8.2	51.4	
11 Sept. 1950	113.7	8.1	54.0	
11 Dec. 1950	113.7	8.1	56.7	

TABLE 9 (Continued)

MAXIMUM TIDE HEIGHTS
BOSTON, MASSACHUSETTS
(ADJUSTED TO 1970)

Date of Occurrence	Maximum Tidal M.D.C.	Elevation M.S.L.	Percent Change of Occurrence In Any One Year	
			1931-1969	1723-1969
4 Apr. 1960	113.7	8.1	59.3	
21 Dec. 1960	113.7	8.1	61.9	
20 Nov. 1937	113.7	8.1	67.2	
17 Jan. 1938	113.7	8.1	69.9	
11 Sept. 1950	113.6	8.0	72.5	
11 Dec. 1950	113.6	8.0	75.1	
1 Dec. 1936	113.5	7.9	77.8	
31 May 1946	113.5	7.9	80.4	
2 Jan. 1948	113.5	7.9	82.9	
30 Nov. 1932	113.5	7.9	85.7	
8 Jan. 1966	113.4	7.8	88.3	
11 Apr. 1922	113.3	7.7	90.9	
3 Mar. 1927	113.3	7.7	93.5	
8 Mar. 1927	113.3	7.7	96.2	
3 Mar. 1942	113.3	7.7	98.8	

K. ANALYSIS OF EXISTING CHARLES RIVER DAM

1. General

The existing Charles River Dam presently carries heavy traffic between Leverett Circle and the Northern Artery. The Dam is a low earth fill structure approximately 1,200 feet in length varying in width from 100 to 500 feet with a large boat lock, and eight sluice gates, each 7.5 feet wide by 10.0 feet high. The large boat lock is 45 feet wide, 350 feet long and has a basin sill at elevation 86.9 feet M.D.C. The large lock is used for locking of all pleasure and commercial craft. The existing large boat lock has sliding lock gates which are not suitable for operation with a differential head and therefore cannot be used for sluicing under present conditions. Following completion of the new Dam the large boat lock will be left open for flow of water. A rating curve of the combined sluicing capacity of the large boat lock and eight sluice gates is shown on Plate 13. A small boat lock, which is located between the sluice gates, is slightly larger in area than a sluice gate. It has been sealed off completely and is no longer available to boat traffic. The gates are used to control basin level by sluicing. The top of Dam is at about elevation 121.0 feet M.D.C. Along each bank of the Basin are the Boston Marginal Conduit and the Cambridge Marginal Conduits which discharge combined sewage overflows to tide water downstream of the existing Dam. The Museum of Science is located on the upstream side of the Dam. The plan and details of the existing Dam are shown on Plate 3 and 10.

2. Flood Flows on the Basin

The Basin is maintained at an elevation of 108.0 feet M.D.C. Overbank flooding of the areas adjacent to the Basin begins when the water level rises above elevation 110.2 feet M.D.C. Since 1954, these floods (Sept. 1954, Aug. 1955, and Mar. 1968) have caused the Basin level to rise above 110.2 feet M.D.C. The August 1955 flood, the flood of record, had a peak flow of about 13,400 cfs causing the Basin to rise to a maximum level of 112.5 feet M.D.C. A comparison of flood flows is shown on Table 6.

3. Operation

At the present time, the large boat lock is used exclusively for the passage of pleasure and commercial boats. The eight, 7.5 foot by 10 foot sluice gates are used to pass the river flows in order to control the Basin levels. The sluice gates are set at an invert elevation of 97.75 feet M.D.C. and the top at elevation of 107.75 feet M.D.C. They are totally dependent on the differential in elevation between the Basin and tide water levels for discharge.During flow periods when the Basin is higher than the tide, there will be a discharge to tide water. However, when the tide level is higher than the Basin, the sluice gates are closed to prevent salt water from entering the Basin. This means that during floods there can be no discharge through sluicing facilities. Therefore, when the tide is higher than the Basin, since the Basin does not have sufficient capacity to store flood flows, and gravity discharge to tide water is restricted, flooding will occur. It is estimated that during each tide cycle there is a 4 to 5 hour period when gravity sluicing is not possible.

When there is advance warning of a severe storm or hurricane, the Basin is pre-lowered from a normal level of 108.0 feet M.D.C. to approximately 107.0 feet M.D.C., thus, giving the Basin more storage capacity during flood flows. However, if the anticipated severe storm or the hurricane does not materialize, there will be a deficiency of water which must be replaced in order to restore the Basin to a normal Elevation 108.0 feet M.D.C.

4. Velocity Through Sluice Gates

At present, during periods when there is heavy discharge through the main sluice gates, the currents caused by sluicing in the downstream channel create problems with the boat traffic. The problem is especially true at the existing B & M and Warren Avenue bridges, downstream of the existing Dam. Sometimes sluicing has to be curtailed to allow boat traffic to travel up and down the river.

5. Conclusion

The original design for the existing Charles River Dam assumed a storm flow discharging from the Upper Watershed only; the subsequent intensive urban development of the Lower Watershed was not, and perhaps could not, be reasonably factored into the design. Examination of Table 6, indicates that for the major floods the Lower Watershed, under present conditions, contributes almost 90% of the peak inflow; even though the area of the Lower Watershed is less than 20% of the total. The peak inflow to the Basin occurs approximately 3 to 4 hours after the peak rainfall while the Upper Watershed inflow peaks some 2 to 3 days later.

Because of the tremendous increase of storm discharge to the Basin, the limited storage capacity of the Basin, and the fact that sluice gates cannot discharge to tide water during a 4 to 6 hour period of the high tide cycle, the gravity discharge facilities cannot alone control the Basin from reaching flood levels. Table 6, summarizes the flow contributions for the Upper and Lower Watersheds for the major floods as well as the maximum flood elevation attained. Plate 5 shows the profile of flood elevations in the Basin for the 1936 and 1955 floods.

L. PLAN OF IMPROVEMENT

1. General

Actual operating experience over a half a century has amply demonstrated that the Lower Basin component of storm inflow requires something other than gravity sluicing to maintain Basin elevation below flood levels. Provision of an adequate pumping facility in the design of a new facility would allow for continous discharge, especially during times when the Basin cannot discharge by gravity to tidewater. Any new Dam facilities must also include adequate gravity sluicing capacity. Pumping will control the Basin within tolerable limits, while a combination of pumping and gravity sluicing will draw the Basin down to normal levels. In addition, the new Dam facility must provide for the adequate locking and nagivation of pleasure and commercial boats; the installation of a fishway; and the decrease of salt water intrusion to the Basin, and the withdrawal of any salt waters which might enter the Basin to tidewater.

2. Proposed Improvements

a. New Charles River Dam - The proposed new Dam will incorporate all the features mentioned above and will be located at the site of the Warren Avenue bridge spanning between the Charlestown and the North End sections of Boston. The location of the new Dam will be approximately 2,250 feet downstream of the existing Dam as shown on Plate No. 10. Approximately 300 acres will be added to the water surface area by locating the new facility at the Warren Avenue site.

30 acres

The new facility will be approximately 560 feet in length, of which 160 feet will be rock armoured embankment with a steel shut piling seepage barrier while the remaining 400 feet will consist of a pumping station, boat lock facilities, and provisions for a fishway. The facility will have a top of dam and top of locks elevation of 118.0 feet M.D.C. base while the normal maintained Basin elevation will remain at 108.0 feet M.D.C. base.

b. Pumping Station - The Metropolitan District Commission has made many investigations and studies to determine the selection of the number, size, and type of pumps, prime movers, and drive transmissions. Model studies of the pumping arrangements were conducted at the Massachusetts Institute of Technology Hydrodynamics Laboratory. A considerable amount of engineering time and model testing has also been performed by pump and engine manufacturers.

It has been determined that the pumping station will have six pumping units with a rated capacity of 1400 c.f.s. each, for a total station capacity of 8,400 c.f.s. Each pump will have a valid capacity of 1,400 c.f.s. at 105.6 r.p.m. discharging against a 9 foot static head. The pumps will have a capacity of 1,260 c.f.s. at 101.5 r.p.m. against an 11 foot static head. Pump and engine operating characteristics and efficiencies are shown on Plates 14 and 15. Flow discharge will be through the vertical pump column which widens to a bellmouth crest at the top. Top of the pump discharge crest will be set at elevation 116.0 feet M.D.C. Discharge will be into an afterbay with a splitter wall. Each pump will be driven through a right angle drive by a diesel engine of about 2,500 brake horsepower.

c. Boat Locks - Studies have been made of both commercial and pleasure boat traffic into the Charles River Basin. Seasonal distribution of boat traffic, types of boats using the locks and boat traffic on peak days were analyzed in detail. From these studies it has been determined that one large boat lock and two small boat locks would best serve the navigational requirements of the Basin. The large lock will be 300 feet in length and 40 feet in width while each of the two small boat locks will be 200 feet in length and 25 feet in width. Investigations were made to determine the type of gates to be used on the boat locks. The types of gates investigated were sector, vertical, left, rolling, double miter, and vascule type. The sector type gate was chosen because it came closest to meeting all the desirable characteristics for this installation including the ability to operate under reversed heads due to tidal conditions, and the requirements of EM-110-2-1604. Resilient seals will also be used in order to prevent salt water intrusion during times when the tide level is above the Basin level. In addition, the selection of sector gates will permit the use of the boat locks for gravity sluicing of flood flows. The lock filling culverts may also be used for sluicing purposes when there is no interference with navigation.

d. Sluicing - Because addition of even a small amount of sluice gate capacity would appreciably reduce the use of the lock culverts for sluicing, additional sluicing capacity will be provided through the dam for normal flows. Progress Report No. 2, "Report Upon Alternate Sites for Charles River Basin Elevation Control Project," for the Metropolitan District Commission recommended a total area of about 200 square feet for sluicing. A study has been made of the physical layout of sluices in the limited available area of the proposed Dam. Two sluices, each 8 feet wide and 10 feet high, have been recommended. One is to be located below the proposed fishway pump and one to the north of the fish ladder. The two sluices, together with the 6 foot by 6 foot sluiceway to be provided in the fish lock, will have about 200 square feet of opening for sluicing purposes. Rating curves for the two 8 foot by 10 foot sluices and the 6 foot by 6 foot sluiceway in the fish lock are shown on Plates 16 and 17.

When the Basin is at a normal level elevation 108.0 feet M.D.C., it has been calculated that the daily outflow through the sluices will average 1,040 c.f.s with normal tide conditions in the harbor. Comparison of this average outflow rate from the Basin indicates that greater inflow might occur 8.5% of the time on approximately 31 days in any one year and additional outflow capacity would be required. However, by utilizing one pump, with rated capacity of 1,400 c.f.s., extra outflow capacity would be required when inflow exceeded 2,440 c.f.s. 1.0% of the time or approximately 4 days in any one year. Use of a second pump for extra outflow capacity would be required less than .5% of the time, or about 1 day in any one year. Because the pumps have to be "exercised" on a regular basis, the use of one or two pumping units for storms of intermediate magnitude would be advantageous. Two 8 feet by 10 feet sluice gates and one 6 feet by 6 feet fish lock sluice gate are considered to be adequate for storms of small magnitude. For major storms, similar to the August, 1955 flood or the project design flood, additional sluicing capacity is extremely useful. Under these conditions, the large boat lock , the small boat locks, and the lock culverts can be utilized for sluicing. Rating curves for these openings are shown on Plates 18, 19, and 20.

In order to withdraw the heavier salt water and silt which accumulates at the bottom of the Basin, one of the 8 foot by 10 foot sluices will be set at the lowest possible elevation.

During the infrequent conditions of major storms when the boat locks are used for sluicing in conjuction with pumping to control the Basin elevation, boat traffic will be curtailed temporarily.

3. Construction Opening

A construction opening, approximately 60 feet wide, will be provided between the proposed cofferdam and the existing bridge pier of the John F. Fitzgerald Expressway. This opening will serve the dual purpose of acting as a navigation channel for boat traffic and also for passing flood flows during the first stages of construction. The construction opening will be dredged to approximately elevation 80.0 feet M.D.C. and the bottom will be protected with rock. With storm outflow of a 20 year frequency (10,000 c.f.s), the channel velocity will be approximately 8 feet per second at mean low water and 6.5 feet per second at mean tide level.

After the pumping station and large boat lock have been constructed, the construction opening will be abandoned. The large boat lock will be used for the passage of pleasure and commercial boats. During major storm flows, the pumping station in combination with the large boat lock, will be used to pass flood flows. When the large boat lock is used for the passage of storm flow, the passage of boat traffic through the large lock will be temporarily stopped.

4. Basis of Design

The Project Design Flood with a peak flow of 15,500 c.f.s. was patterned after the Hurricane Diane storm flow of August 1955. The "Standard Project Flood" with peak flow of 20,000 c.f.s. was determined following the procedure as outlined in Corps of Engineers Bulletin 52-8, and the hydrograph of the August 1955 flood. The hydrographs for the August, 1955 flood, the "Project Design Flood" and the "Standard Project Flood" are shown on Plate 6.

In routing the "Project Design Flood" and the "Standard Project Flood" through the proposed Dam, the Design tide has been taken to have a maximum elevation of 113.0 feet M.D.C., (2.8 feet above mean high tide), a low elevation of 102.7 feet M.D.C. (1.9 feet above mean low tide). For study purposes, it has been assumed that the highest inflows for the above mentioned storms occur during the period of no gravity sluicing at approximately the same time as the design high tide elevations. As a consequence, at the time of storm flow the tide level remains above the normal Basin level for more than six hours. The "Design Tide" cycle is shown on Plate 11.

The design studies have been premised on the assumption that pumping begins when the Basin level reaches 107.5 ft.M.D.C. after prelowering by sluicing to 107.0 feet M.D.C.

5. Effect of Channel Between Existing Dam and Proposed Dam

The channel between the upstream face of the existing Dam (Science Park) and the forebay of the proposed Dam restricts the total discharge capacity. The main restriction occurs at the existing Dam where the flow must pass either through the existing lock (with a streamlined entrance) or the existing sluice openings. Some restriction to flow occurs at the narrows of the Boston and Main Railroad Bridge downstream of the present Dam. These restrictions cause high channel velocities and corresponding head losses when both pumps and sluices are operative in the new facility. Plate 21 is a rating curve indicating the drawdown between the headwater at the present Dam and the forebay area of the proposed facility. As an example, if the Basin (headwater at present Dam) were at elevation 109.0 feet M.D.C., a total flow of 16,000 c.f.s. would result in a total level drop of about 3.5 feet at the forebay.

Table 10 indicates the drawdown resulting from various discharges up to 8,400 c.f.s. between the headwater at the present Dam and the forebay at the proposed facility at a relatively low Basin elevation of 107.5 feet M.D.C.

6. Prelowering

The design studies have been premised on the assumption that pumping begins when the Basin level reaches 107.5 feet M.D.C after prelowering by sluicing to 107.0 feet M.D.C. in anticipation of storm flows. Under design conditions of Project Design peak flood (15,500 c.f.s.) coincident with design high tide (113.0 feet M.D.C.), continous pumping at a rate of 8,400 c.f.s., and starting the pumps at 107.5 feet M.D.C. would result in a maximum Basin elevation of 109.6 feet M.D.C. Under similar conditions for the Standard Project Flood (20,000 c.f.s.) would result in a maximum Basin elevation of 111.3 feet M.D.C. However, prelowering to elevation 106.5 feet M.D.C. and starting pumping at elevation 106.5 feet M.D.C. rather than 107.5 feet M.D.C. with all other design conditions the same would result in a maximum Basin elevation of 110.5 feet M.D.C. rather than 111.3 feet M.D.C.

TABLE 10

FOREBAY ELEVATION WITH CONSTANT BASIN ELEVATION @ 107.5

Discharge (c.f.s.)	Head Loss (feet)*	Forebay Elevation (M.D.C.)
0	0	107.5
2,000	0.1	107.1
4,000	0.3	107.2
6,000	0.6	106.9
8,400	1.1	106.4

* Includes channel losses from proposed to existing Dam and losses in sluicing facilities through the existing Dam.

7. Effect on Forebay

As mentioned in paragraph L-5, the total discharge through the present Dam facilities and the downstream channel are restricted. In order to maintain the maximum Basin rise within tolerable limits, the Basin must be drawn down prior to the peak of the storm. In order to draw down the Basin, the elevation in the pump forebay must drop considerably. Plate 6 indicates the drawdown elevations required at the forebay for the Project Design Flood and the Standard Project Flood. As shown for the Project Design Flood and the Standard Project Flood, with the Basin at the start of pumping at 107.5 feet M.D.C., the forebay, will drop to elevation 106.4 feet M.D.C. For the Standard Project Flood, with pumping starting at elevation 106.5 feet M.D.C., the forebay will drop to elevation 105.2 feet M.D.C. Therefore, any development of the forebay (area between existing and proposed Dam facilities) must take cognizance of the fluctuations of water surface elevation under severe storm conditions between a minimum of about 105.0 feet M.D.C. and a maximum of about 110.5 feet M.D.C.

8. Operation

a. Advance Warning - As soon as there is a warning of an approaching major storm or hurricane with possible heavy precipitation or runoff, the normal Basin level of 108.0 feet M.D.C. is prelowered to elevation 107.5 feet M.D.C. or lower. This is accomplished by pumping and/or sluicing depending on tide conditions.

A rain gauge or prelowering indicator as recommended in Section M 2a and described later in this Memorandum should be used as a basis of prelowering the Basin. This indicator is based on the ratio of the lower watershed area to Basin area, and the time lag between storm and flood. Therefore, an accumulation of one foot in the rain gauge corresponds to a one foot rise in the Basin with no outflow. Conversely, if the Basin is prelowered one foot, it would be reasonable to assume the Basin would return to at least its original elevation after several hours.

During the major flood, if the tide elevation is above the Basin level, gravity sluicing is not possible, therefore, pumping is utilized to control the Basin level. When the Basin elevation is greater than the falling tide level, pumping can be used with gravity sluicing to draw down the high Basin level.

b. Boat Navigation - During a major flood when the rate of pumping and gravity sluicing is high, navigation would have to be curtailed. This is due to high channel velocities, especially at the existing large boat lock. However, since large flows normally occur in the early spring when pleasure boat traffic is light, the interference of pumping and gravity sluicing with boat traffic should be infrequent. It is estimated that interference with commercial vessel traffic will begin when the flow velocity through the existing lock reaches about one foot per second, and with pleasure boat traffic when the flow velocity through the lock reaches about two feet per second. These conditions occur with discharges of approximately 1,500 c.f.s and 3,000 c.f.s. respectively, by pumping and/or sluicing. It is estimated that the operation of one pump combined with maximum sluicing of 2,000 c.f.s. (total flow of 3,400 c.f.s.) resulting in a maximum velocity in the existing lock of about 2.2 feet per second would be sufficient 99% of the time. Operation of two pumps combined with maximum sluicing of 2,000 c.f.s. (total flow of 4,800 c.f.s.) resulting in a maximum velocity of 3.0 feet per second in the existing large boat lock would occur about 1% of the time (about 4 days per year), and would result in interference with pleasure boat navigation.

c. Project Design Flood - Under design conditions peak flood (15,500 c.f.s.) coincident with design high tide (113.0 feet M.D.C.), Basin prelowered to 107.5 feet M.D.C. at the start of pumping, and pumping at 8,400 c.f.s. would result in a maximum Basin elevation of 109.6 feet M.D.C. As shown on Plate 6, gravity discharge would not be possible for almost 5.5 hours, and from the time when gravity discharge could be utilized together with pumping to lower the Basin, approximately 4 hours would be required to draw the Basin down to a normal elevation of 108.0 feet M.D.C. Under similar design conditions, assuming one pump inoperative, the Basin would rise to a maximum elevation of 110.5 feet M.D.C. If an additional pump (1,400 c.f.s.) were added to the pump capacity of 8,400 c.f.s., the maximum elevation would be 109.2 feet M.D.C.

d. Standard Project Flood - As shown on Plate 6 for Standard Project Flood conditions with the Basin prelowered to elevation 107.5 feet M.D.C. continuous pumping of 8,400 c.f.s. would result in a peak Basin elevation of 111.3 feet M.D.C.; continuous pumping of 7,000 c.f.s. (one pump inoperative) would result in a peak elevation of 111.8 feet M.D.C.; and continuous pumping of 9,800 c.f.s. (one additional pump) would result in a peak elevation of 110.6 feet M.D.C.

If the Basin were to be prelowered to elevation 106.5 feet M.D.C. continuous pumping of 8,400 c.f.s. would result in a peak, Basin elevation of 110.5 feet M.D.C.; continuous pumping of 7,000 c.f.s. (one pump inoperative) would result in a peak elevation of 111.0 feet M.D.C., and continuous pumping of 9,800 c.f.s. (one additional pump) would result in a peak elevation of 109.8 feet M.D.C.

The cost of an additional pumping unit and facility would be well over one million dollars. With six pumps and a pumping rate of 8,400 c.f.s., prelowering the Basin to 106.5 feet M.D.C., the Basin level can be controlled to a maximum elevation of 110.5 feet M.D.C.

It is estimated that overland flooding damages in the Basin start at approximately elevation of 110.2 feet M.D.C. The Corps of Engineers in its Charles River Lower Basin Interim Report estimated that for a flood elevation of 110.7 feet, the damage is estimated to be $400,000. Therefore, by the judicious use of prelowering, the flood damage of areas adjacent to the Charles River Basin can be greatly reduced during the Standard Project Flood and an additional expenditure for an extra pumping unit cannot be justified.

e. Gravity Sluicing - During a Project Design Flood or a Standard Project Flood under stated design conditions, continuous pumping by itself cannot maintain the Basin below flooding levels. Pumping alone will not control the Basin levels within the desired limits and a combination of pumping and gravity sluicing are required to provide adequate control.

Two systems of gravity sluicing have been studied. The first system assumes the use of a combination of one fish lock, two 8 foot x 10 foot sluice gates, and two small boat locks together with continuous pumping of 8,400 c.f.s. This system proved to be unsatisfactory because the maximum Basin level was prolonged over several hours and the drawdown to a normal Basin was very slow and could not be achieved within one tide cycle.

The second system assumed the use of a combination of one fish lock, two 8 foot x 10 foot sluice gates and one large boat lock together with continuous pumping of 8,400 c.f.s. for sluicing. This system proved to be satisfactory because a continuous draw down could be achieved almost instantaneously and a normal Basin level could be reached before the next rising tide cycle. Plate 6 indicates the fluctuating Basin levels and the design tide cycle for various time intervals. Plate 22, 23, and 24 indicate the rating curves for a system of sluicing between the headwater at the present Dam and tail water at the proposed Dam. This sluicing system includes the facilities at the existing Dam (one large boat and eight 7.5 foot x 10 foot sluices gates), the channel between the present and proposed Dams, and a combination of a continuous pumping rate of either 7,000, 8,400, and 9,800 c.f.s. together with gravity sluicing of one fish lock, two 8 foot by 10 foot sluice gates, and one large boat lock.

9. Conclusions

a. If the 7.5 foot by 10 foot sluice gates were removed at the existing Dam and the existing small boat lock reopened for sluicing purposes, the velocities through the existing large boat lock would be reduced by about 7% and the head losses would be reduced resulting in an increase in the pump forebay elevations of about 0.2 feet.

b. If the Boston and Maine Railroad Bridge could be removed, the pump forebay elevations could be increased by about 0.5 feet.

c. Improvements to channel between existing and proposed Dams by dredging would improve discharge conditions and reduce head losses between the present and proposed facilities.

d. Prelowering of the Basin must be used for major floods in order to control the maximum Basin elevation within tolerable limits.

e. For the Standard Project Flood, prelowering the Basin to elevation 106.5 feet M.D.C. results in a minimum pump forebay elevation of 105.2 feet M.D.C. and a maximum Basin elevation of 110.5 feet M.D.C.

f. During a Standard Project Flood the forebay (area between existing and proposed dams) will fluctuate between a minimum elevation of about 105.0 feet M.D.C. and a maximum of 110.5± feet M.D.C. Any development of the forebay area must take into account this fluctuation.

g. During a Project Design Flood or a Standard Project Flood, pumping without sluicing cannot control the maximum Basin rise within tolerable limits.

h. During a Project Design Flood and a Standard Project Flood a combination of pumping and sluicing is required to draw the Basin down to normal levels.

i. For a Project Design Flood and a Standard Project Flood a combination of one fish lock, two 8 foot by 10 foot sluice gates and one large boat lock can provide adequate sluicing capacity.

j. During major storms, boat traffic will have to be curtailed.

M. Miscellaneous

1. Salt Water Intrusion - At times the existing Basin has a high salt water content caused by low flow in the Charles River, the inflow of a large volume of salt water through the existing boat lock when the upper lock gate is opened, and leakage through the earth fill Dam, the lock gates and the sluices. It is estimated that 60% of the salt water in the large boat lock is interchanged with the fresh Basin water in five minutes time. Construction of improved facilities at the new Dam will help to alleviate these problems. Leakage through the Dam, lock gates and sluices will be greatly reduced. Judicious use of the small boat locks with their much smaller volumes will cut down substantially the inflow of salt water from locking operations. The ability to pump the flood flows from the Charles will reduce the need to lower the Basin in anticipation of approaching storms. This procedure will help to conserve the fresh water during the periods of low flow. Also the elevation of the pump intakes and the sluice gates will be set as low as possible in order to flush out the heavier salt water that lies on the bottom.

2. Instrumentation

The instrumentation for this project shall include devices for measurements and indication of levels and flows as follows:

a. A rain gauge prelowering indicator as developed in the Metropolitan District Commission's "Analog Studies, Charles River Basin Outlet Facilities, Second Progress Report" and shown in "Progress Report No. 3, Report upon Alternate Types of Pumping Equipment for Charles River Basin, Dec. 1959", shall be placed at the existing Dam.

b. Basin level recorders at the present Dam; one to measure the headwater level and one to measure the tailwater level.

c. Basin level recorders at the proposed Dam; one to measure the headwater levels and one to measure tide levels.

d. Level recorders; one for the large boat and one for each of the small boat locks.

e. Level recorders at the Silk Mill Dam, at the Waltham Dam and at Watertown.

In addition, salinity measurements at two levels shall be made at the B.U. Bridge and at the present Dam.

All the information on the above mentioned measurement devices shall either be recorded at, or telemetered to, a console for display and/or recording of these measurements to be located in the control towers of the new Dam. The instrumentation system is necessary to provide the operator with sufficient information to efficiently operate the boat lock system, control Basin and forebay levels, and control pumping and sluicing operations.

Instrumentation for the measurement of water quality and water pollution monitoring will not be provided under the contract for this project by the Corps of Engineers, but will be provided in conjunction with the proposed contract by the M.D.C. for collection, pumping, and treatment of Boston and Cambridge Marginal Conduit outlets and other overflows between the existing and proposed Dams. This project is presently in the preliminary design stages, and, when completed, will reduce pollution in the existing Charles River Basin, the extension of the Basin between the existing and proposed Dams, and Boston Harbor.

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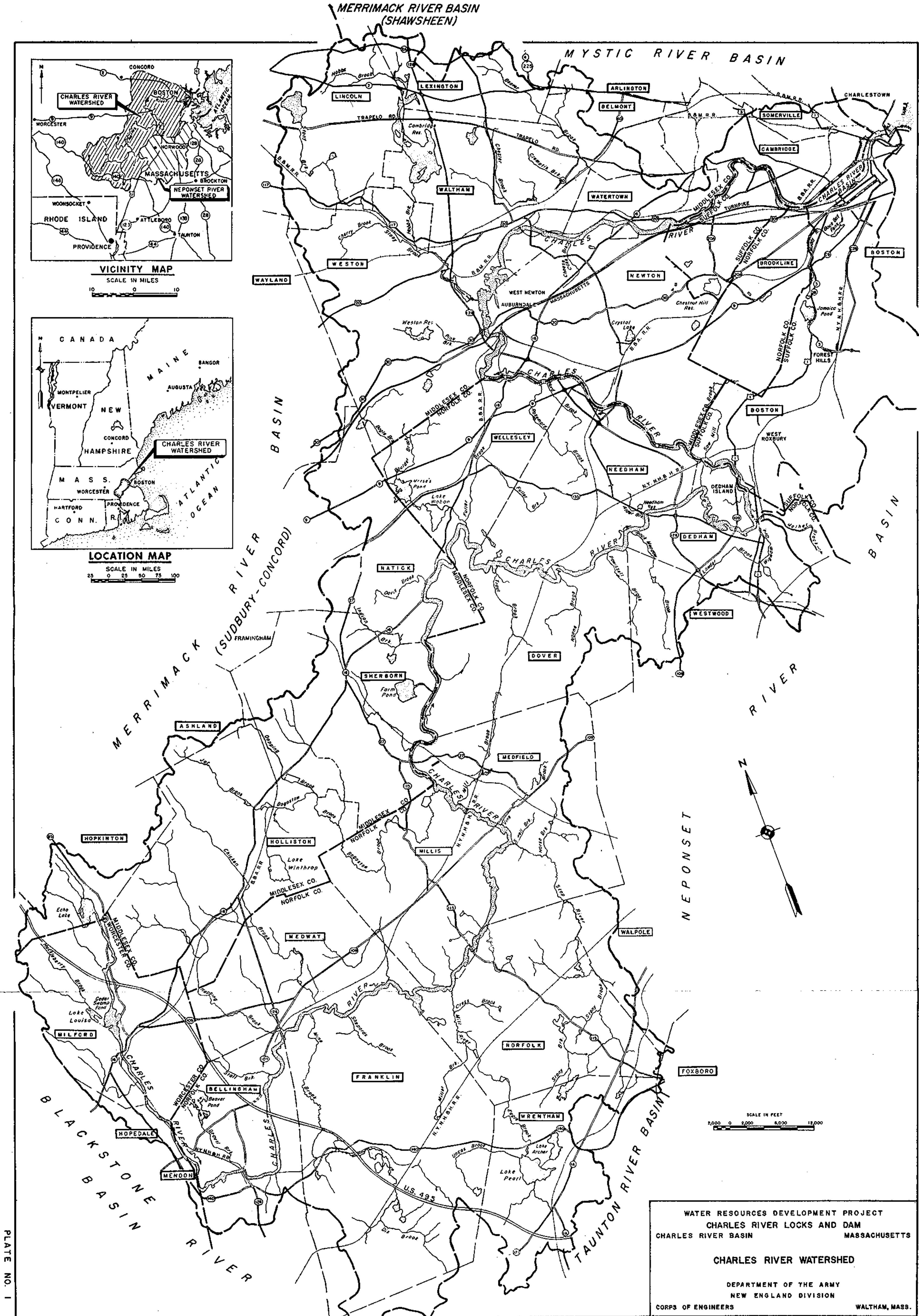


WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS

CHARLES RIVER WATERSHED

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 1

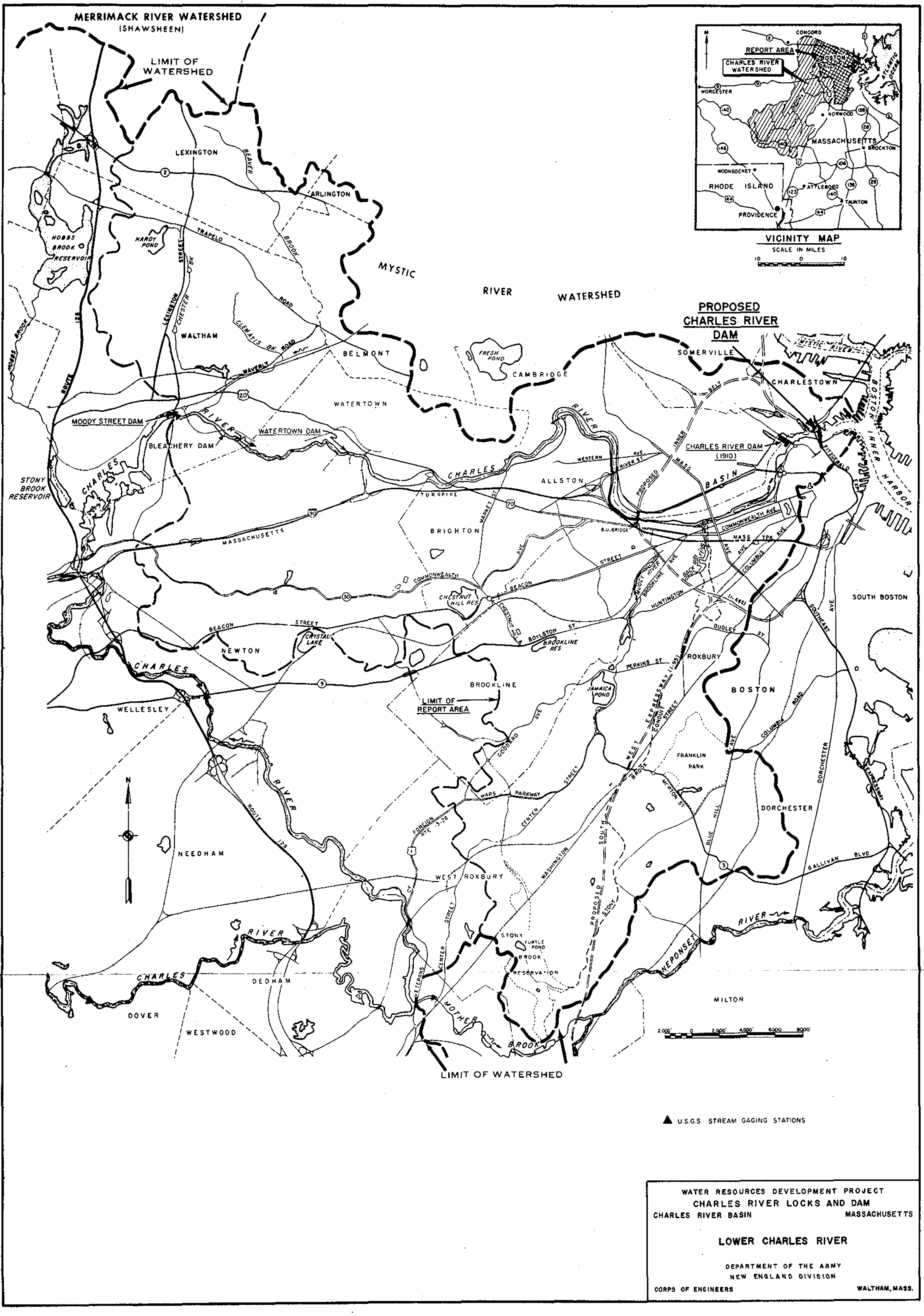
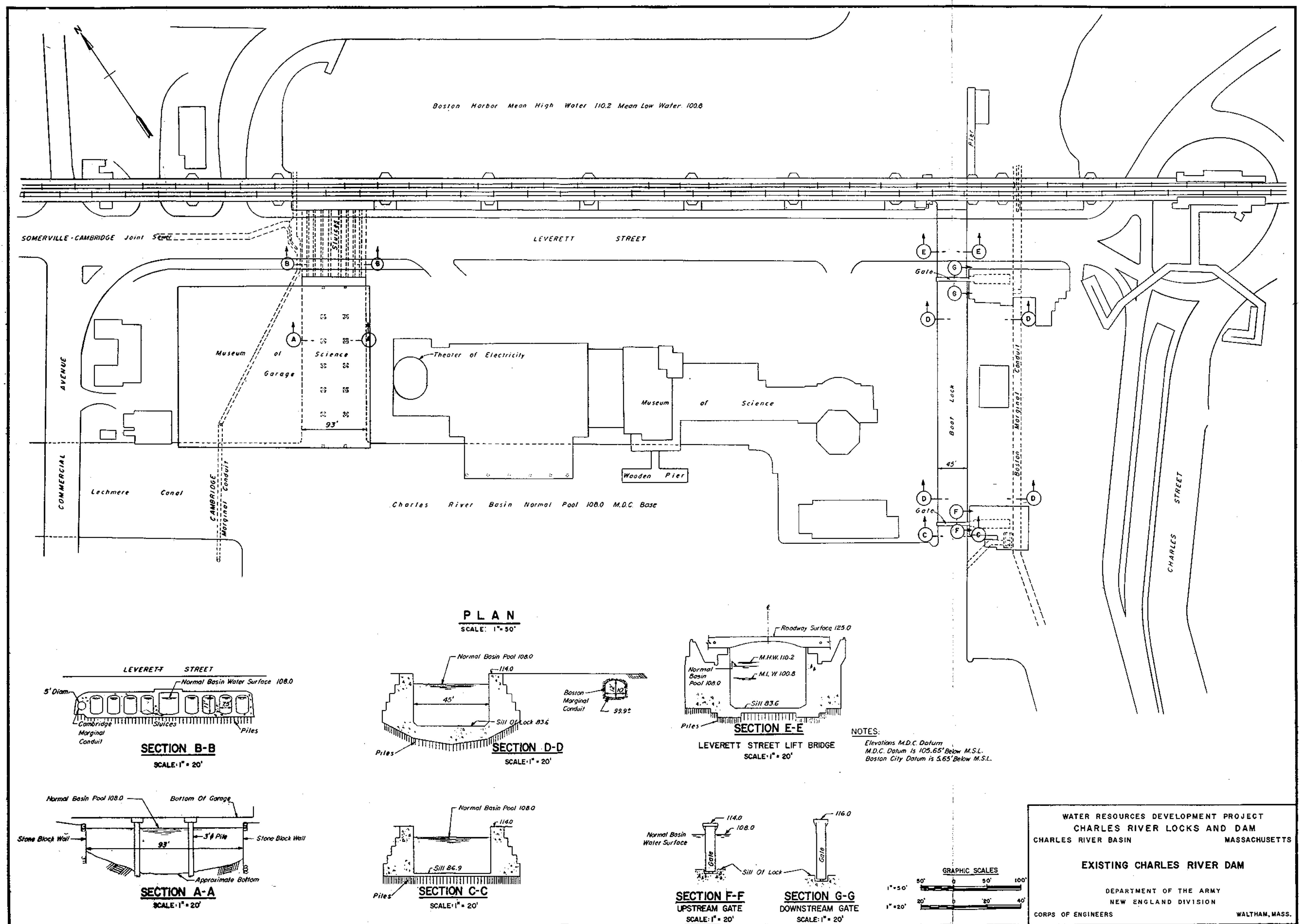

MERRIMACK RIVER WATERSHED
(SHAWSHEEN)
LIMIT OF WATERSHED
MYSTIC RIVER WATERSHED
PROPOSED CHARLES RIVER DAM
VICINITY MAP
SCALE IN MILES
REPORT AREA
CHARLES RIVER WATERSHED
CONCORD
BOSTON
WORCESTER
NORWOOD
MASSACHUSETTS
BROCKTON
WOONSOCKET
RHODE ISLAND
ATTLEBORO
TAUNTON
PROVIDENCE
ATLANTIC OCEAN
LEXINGTON
ARLINGTON
HOBBS BROOK RESERVOIR
HARDY POND
WALTHAM
BELMONT
FRESH POND
CAMBRIDGE
SOMERVILLE
CHARLESTOWN
WATERTOWN
MOODY STREET DAM
BLEACHERY DAM
WATERTOWN DAM
CHARLES RIVER DAM
(1910)
STONY BROOK RESERVOIR
ALLSTON
BRIGHTON
CHARLES RIVER BASIN
BOSTON INNER HARBOR
CHESTNUT HILL RES
BROOKLINE RES
NEWTON
CRYSTAL LAKE
SOUTH BOSTON
ROXBURY
BOSTON
BROOKLINE
LIMIT OF REPORT AREA
WELLESLEY
JAMAICA POND
FRANKLIN PARK
DORCHESTER
NEEDHAM
WEST ROXBURY
STONY BROOK RESERVATION
TURTLE POND
NEPONSET RIVER
MOTHER BROOK
MILTON
DEDHAM
DOVER
WESTWOOD
LIMIT OF WATERSHED
▲ U.S.G.S. STREAM GAGING STATIONS
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN
MASSACHUSETTS
LOWER CHARLES RIVER
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE NO. 2

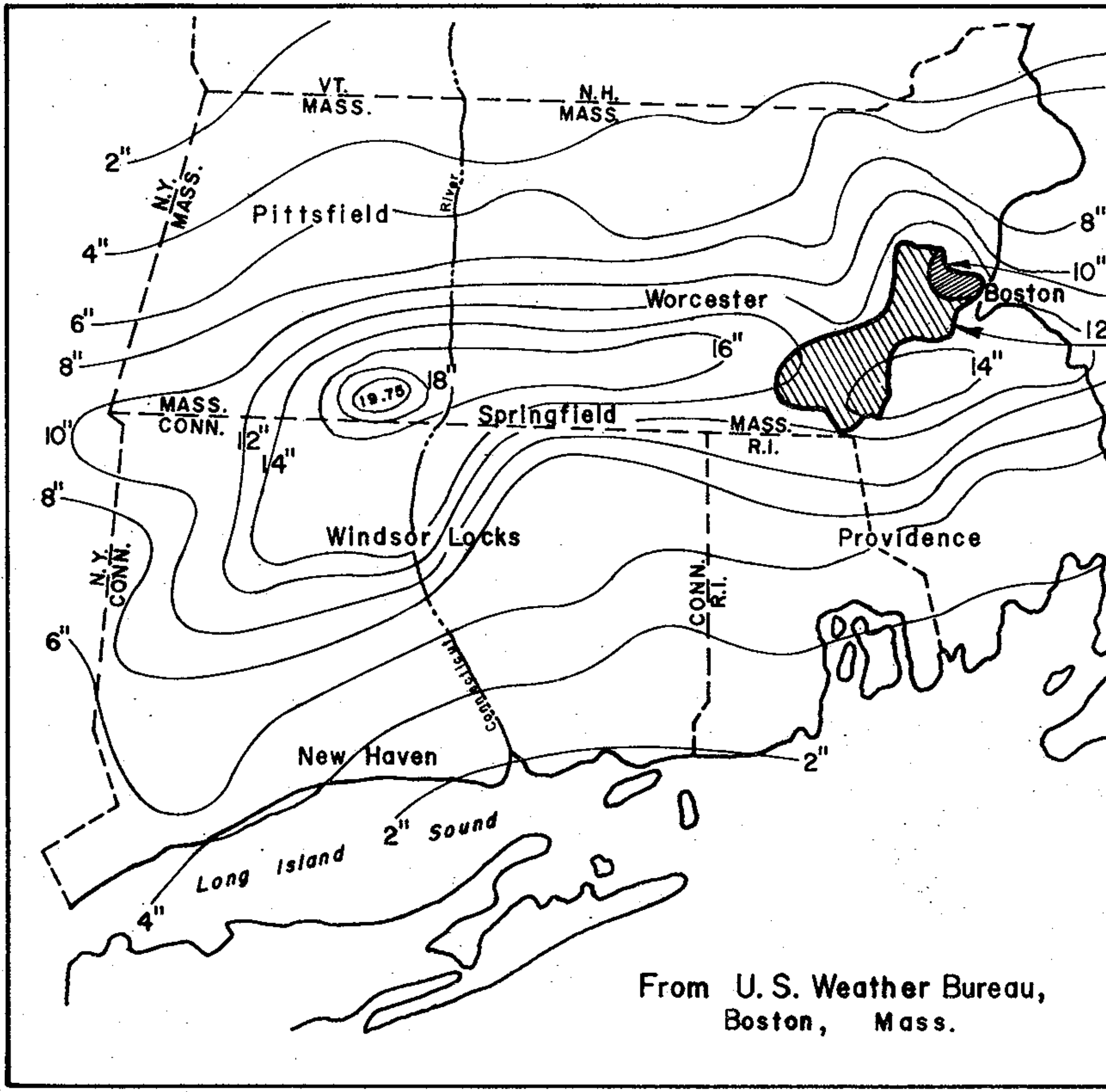


WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS

EXISTING CHARLES RIVER DAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO.3



WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

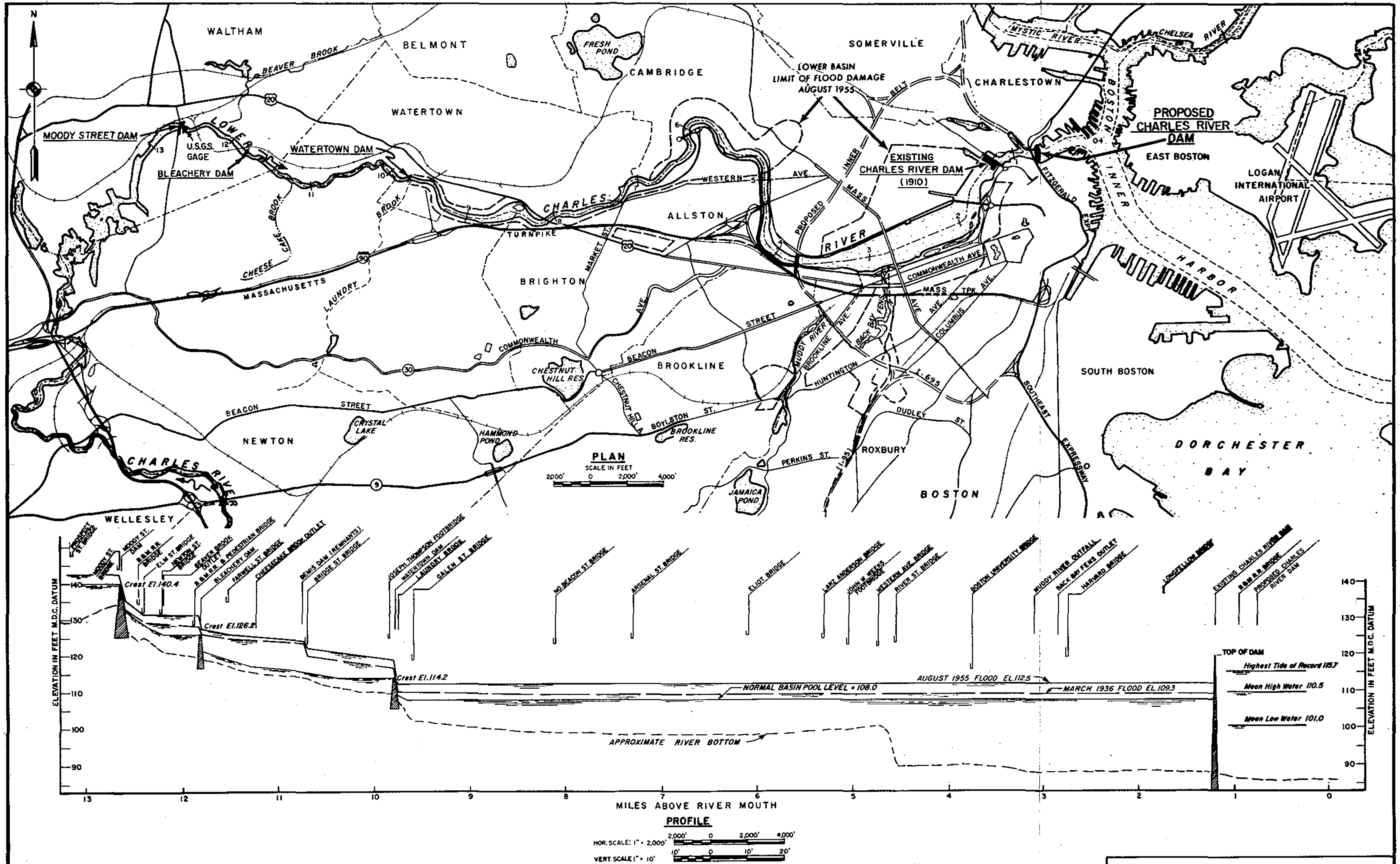
CHARLES RIVER BASIN MASSACHUSETTS

ISOHYETAL MAP

STORM OF AUGUST 17–19 1955

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 4

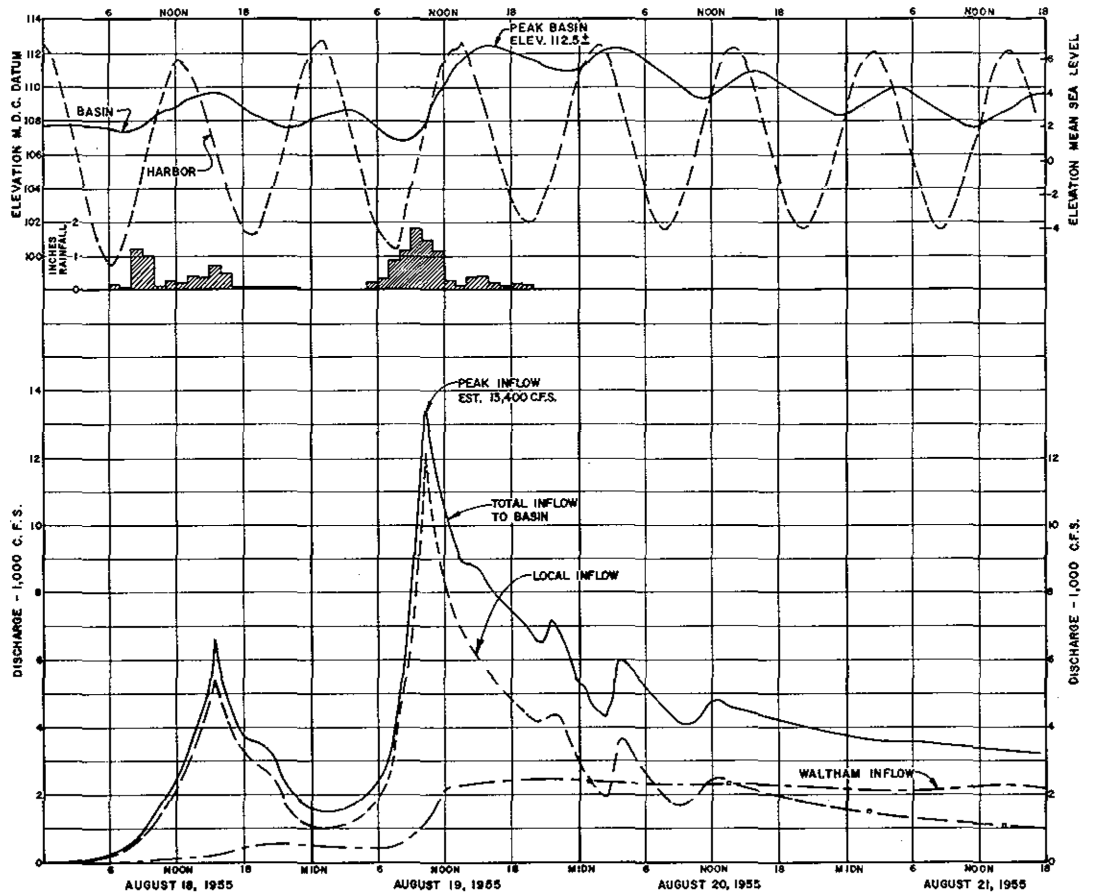


WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS

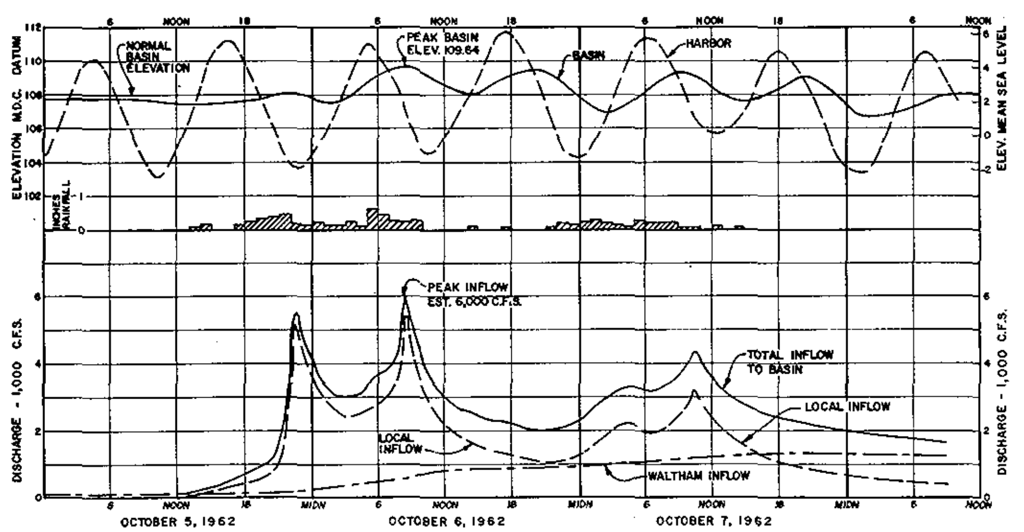
CHARLES RIVER – MOODY ST. TO WARREN AVE.
PLAN AND PROFILE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

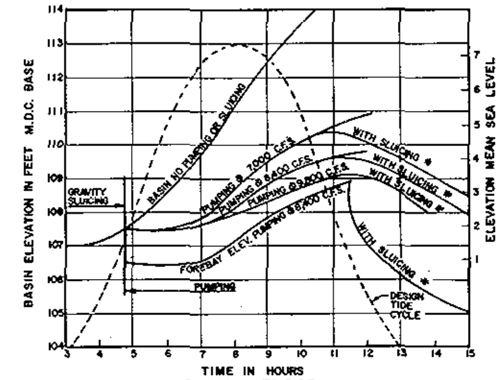
PLATE NO. 5



FLOOD OF AUGUST 18-21, 1955

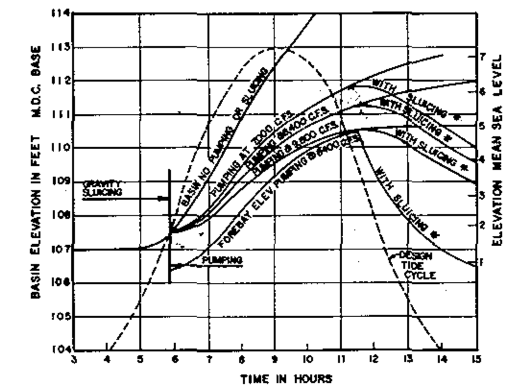


FLOOD OF OCTOBER 5-7, 1962



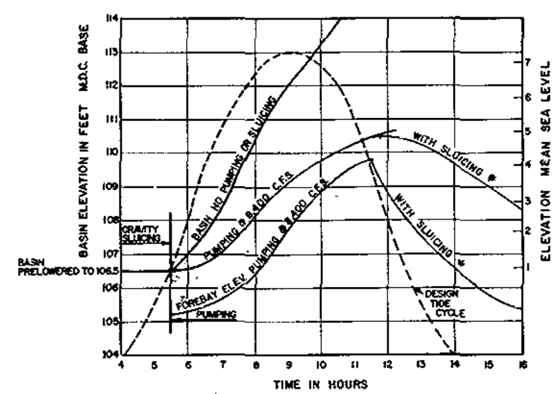
DESIGN FLOOD

(PK. = 15,500 C.F.S.)



STANDARD PROJECT FLOOD

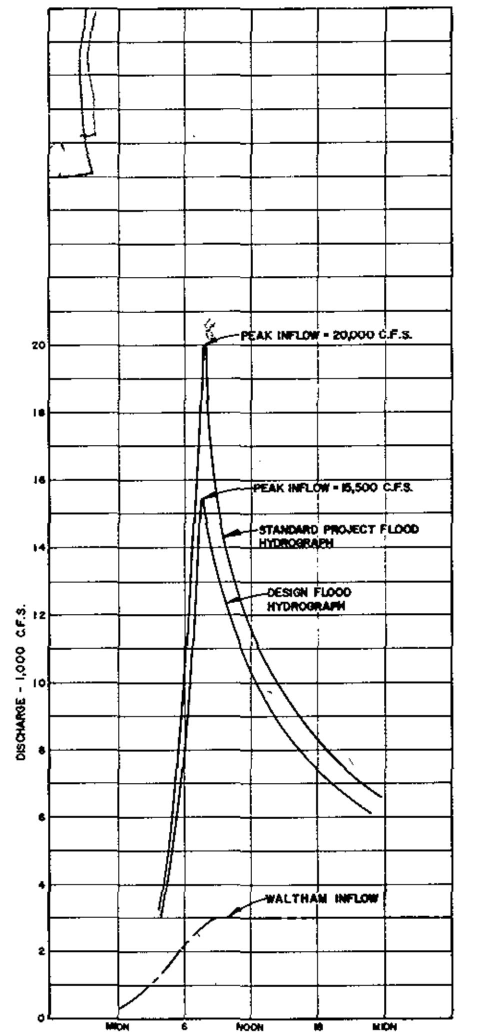
(PK.= 20,000 C.F.S.)



STANDARD PROJECT FLOOD 20,000 C.F.S.

(BASIN PRELOWERED TO ELEVATION 106.5)

* Sluicing through two 8'x10' sluices, one large boat lock and one 6' fish lock.



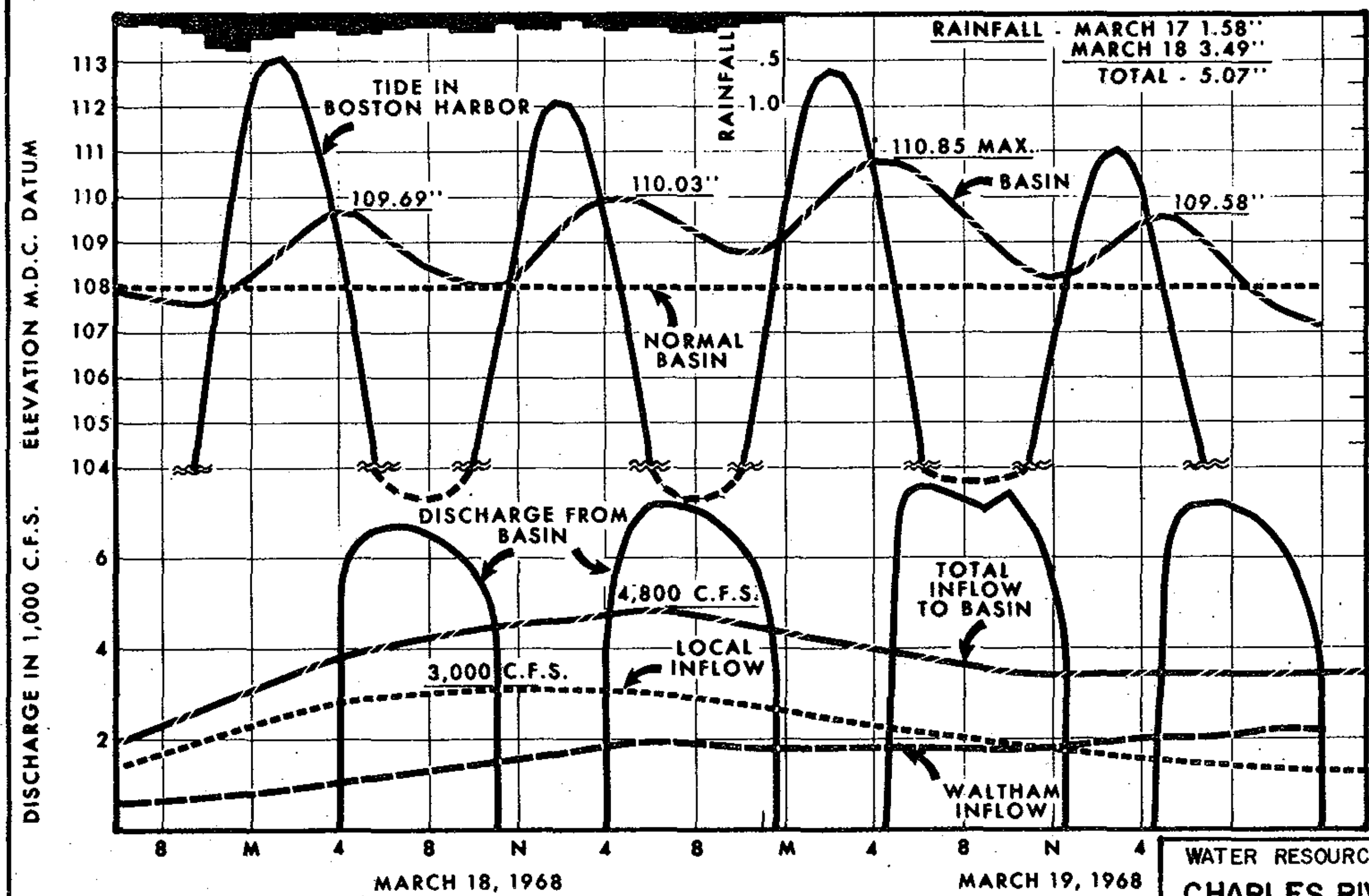
STANDARD PROJECT FLOOD AND DESIGN FLOOD HYDROGRAPHS

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS

FLOOD HYDROGRAPHS - AUG. 1955, OCT. 1962 STANDARD PROJECT FLOOD, PROJECT DESIGN FLOOD

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 6



WATER RESOURCES DEVELOPMENT PROJECT

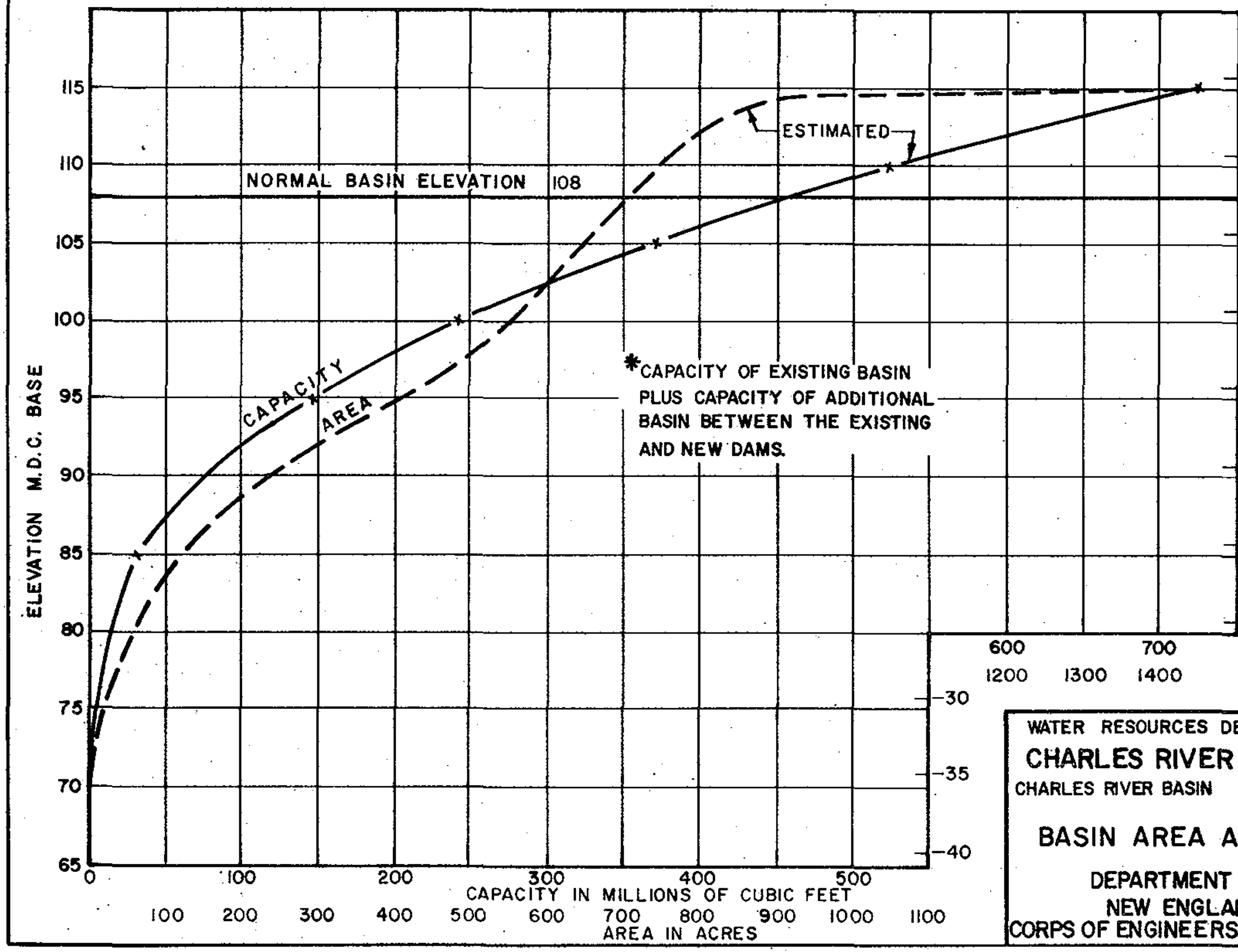
CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

FLOOD HYDROGRAPH
MARCH 18-19 1968

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS. OF ENGINEERS WALTHAM, MASS.

PLATE NO. 7



WATER RESOURCES DEVELOPMENT PROJECT

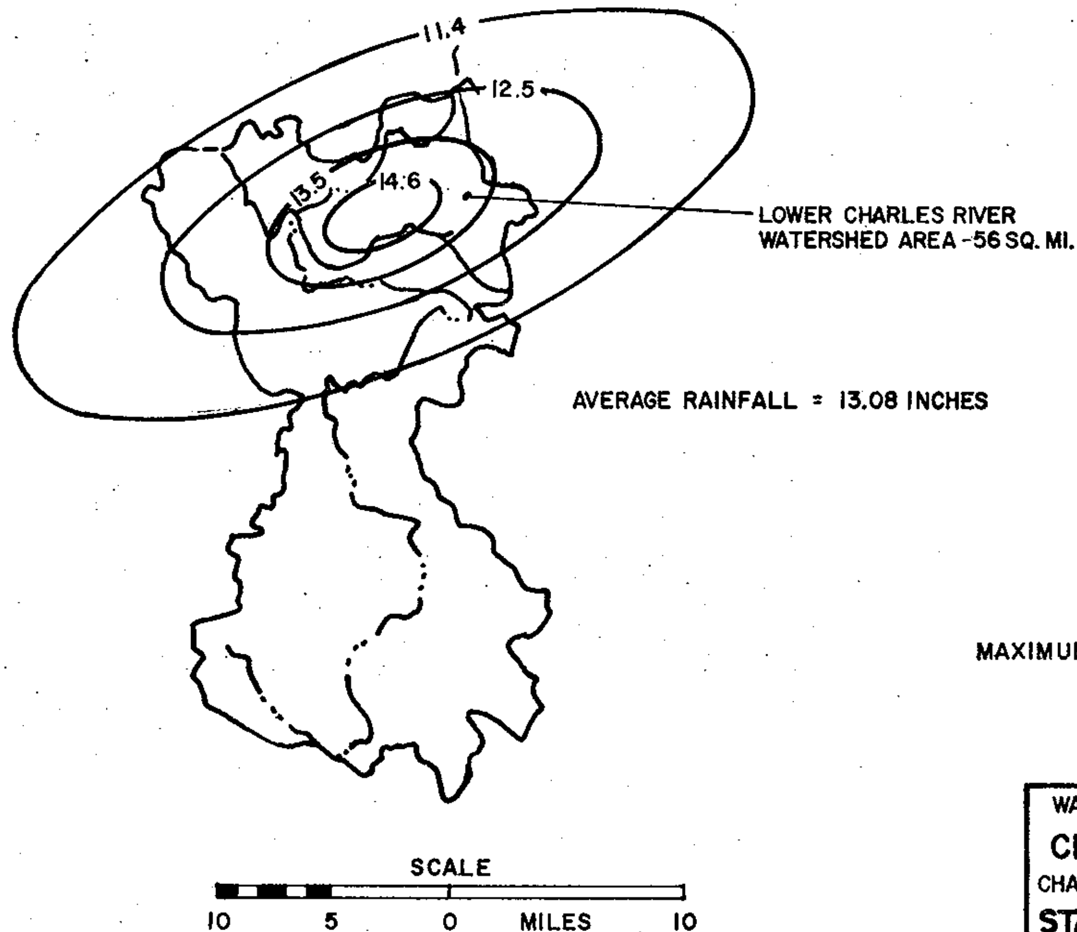
CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

BASIN AREA AND CAPACITY*

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 8



MAXIMUM 96 HOUR PERIOD OF S. P. S.

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

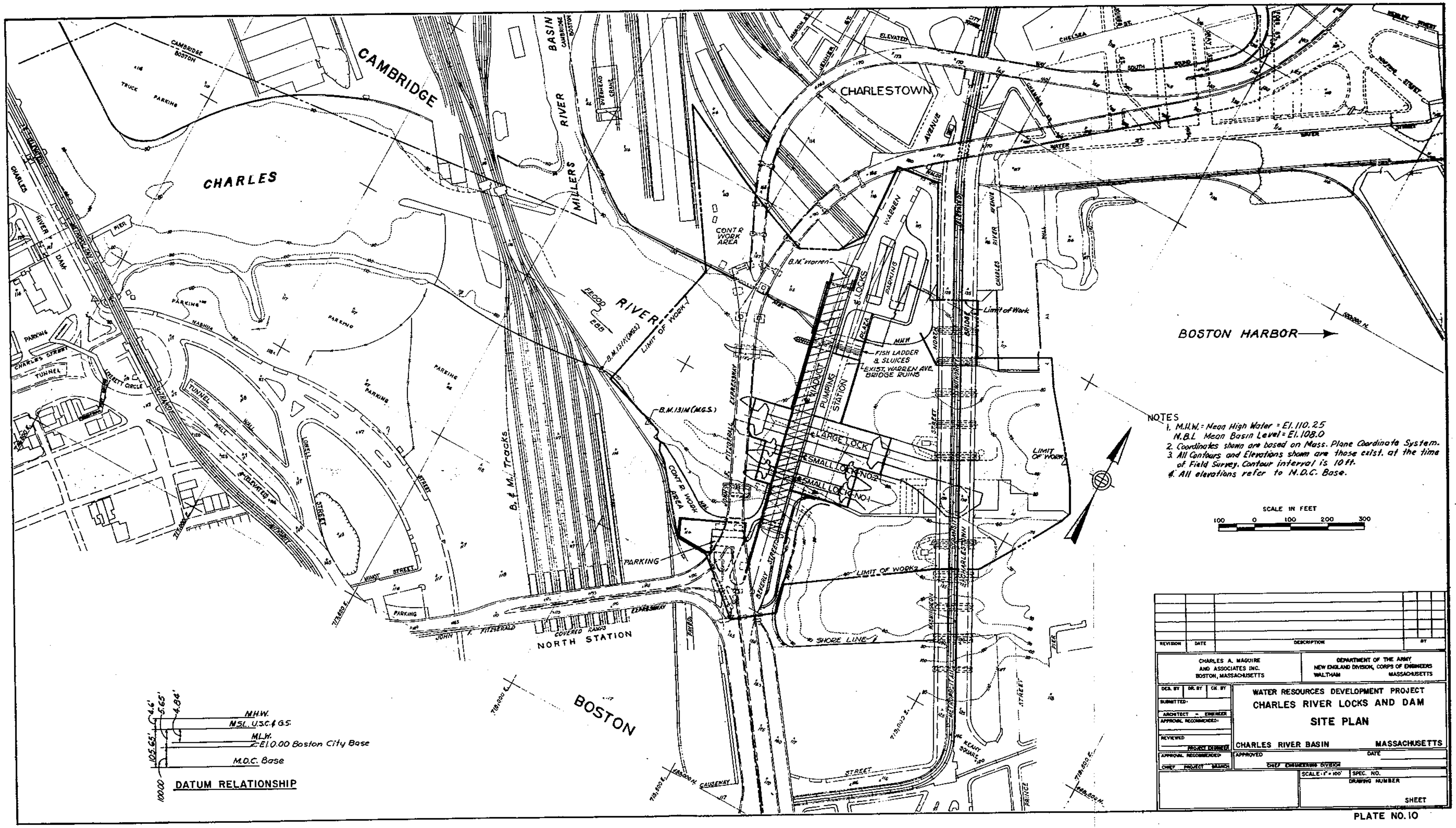
CHARLES RIVER BASIN MASSACHUSETTS

STANDARD PROJECT STORM STUDY

ISOHYETAL PATTERN

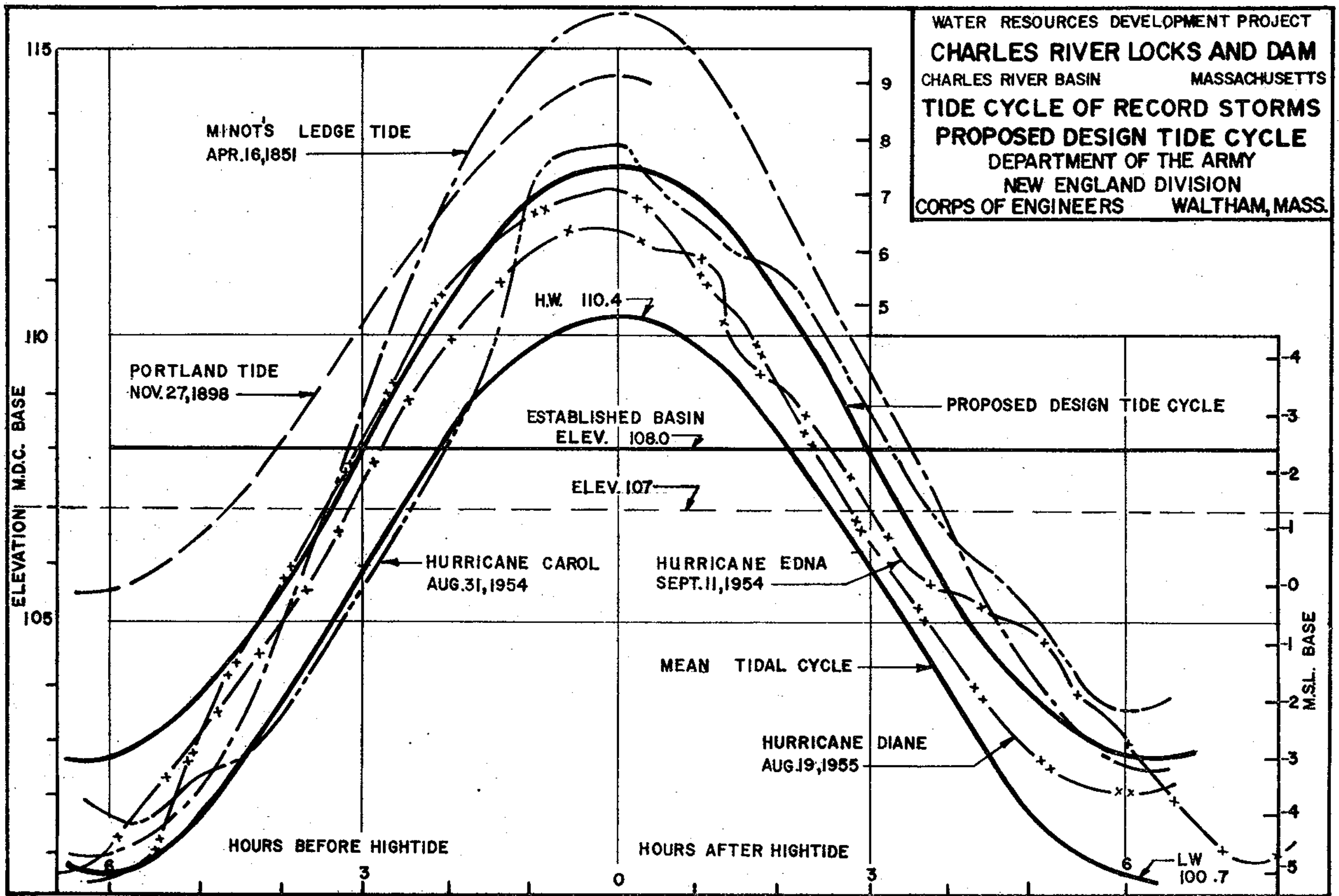
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 9



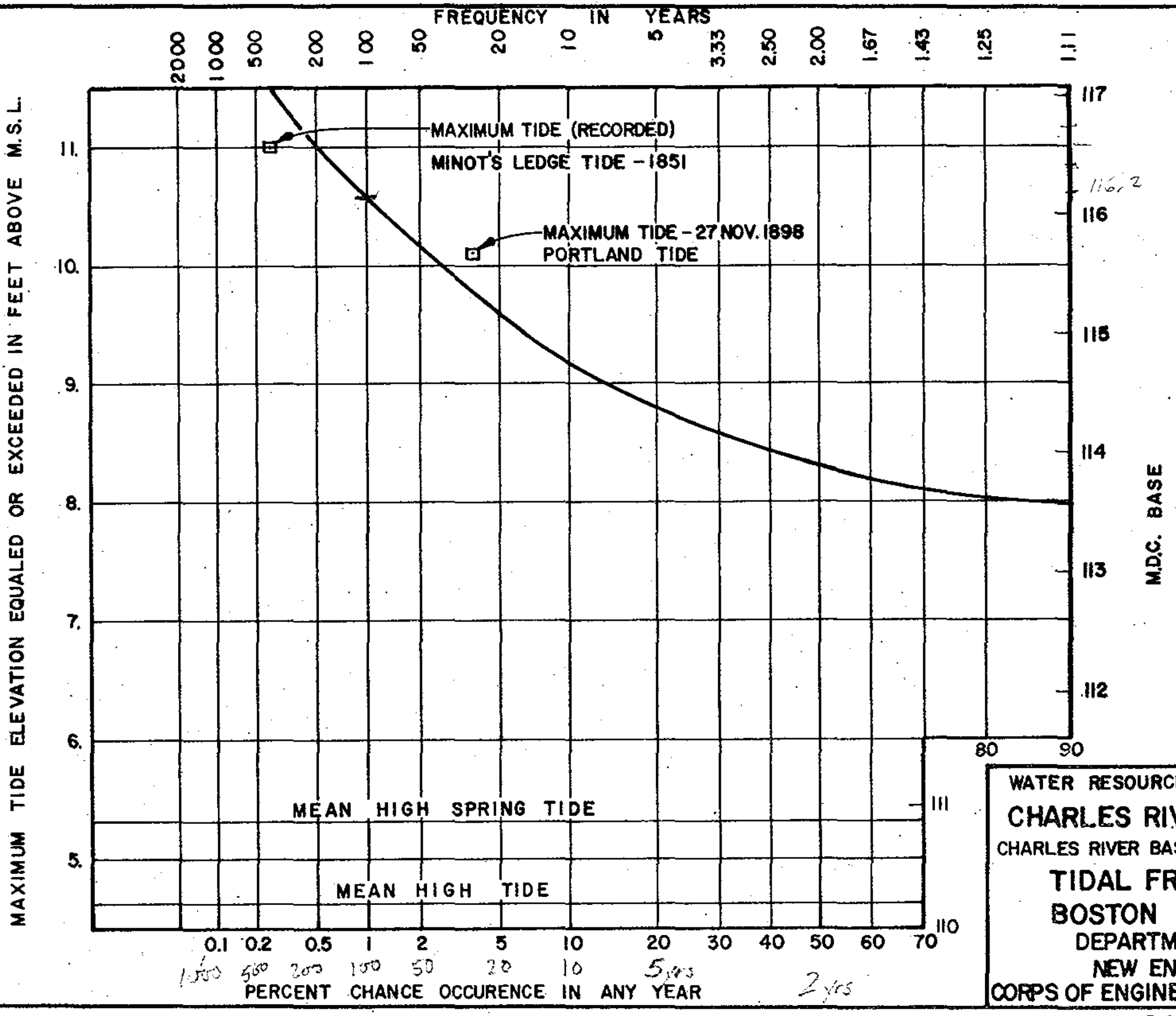
CAMBRIDGE
CHARLES
RIVER
MILLERS RIVER BASIN
CHARLESTOWN
BOSTON HARBOR
BOSTON
CONTR WORK AREA
LIMIT OF WORK
B.M. "Warren"
LOCKS
PARKING
FISH LADDER & SLUICES
EXIST. WARREN AVE. BRIDGE RUINS
PUMPING STATION
LARGE LOCK
SMALL LOCK NO. 2
SMALL LOCK NO. 1
B.M. 131M (M.G.S.)
B. & M. Tracks
NORTH STATION
SHORE LINE
CHARLES RIVER DAM
CHARLESTOWN BRIDGE
NORTH WASHINGTON STREET
KEANY SQUARE
NOTES
1. M.H.W. = Mean High Water = El. 110.25
N.B.L. Mean Basin Level = El. 108.0
2. Coordinates shown are based on Mass. Plane Coordinate System.
3. All Contours and Elevations shown are those exist. at the time of Field Survey. Contour interval is 10 ft.
4. All elevations refer to M.D.C. Base.
SCALE IN FEET
100 0 100 200 300
M.H.W.
M.S.L. U.S.C.& G.S.
M.L.W.
El. 0.00 Boston City Base
M.D.C. Base
4.4'
5.65'
4.84'
105.65'
100.00
DATUM RELATIONSHIP
REVISION
DATE
DESCRIPTION
BY
CHARLES A. MAGUIRE AND ASSOCIATES INC. BOSTON, MASSACHUSETTS
DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION, CORPS OF ENGINEERS WALTHAM MASSACHUSETTS
WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
SITE PLAN
CHARLES RIVER BASIN MASSACHUSETTS
APPROVED
DATE
CHIEF ENGINEERING DIVISION
SCALE: 1" = 100'
SPEC. NO.
DRAWING NUMBER
SHEET

PLATE NO. 10



WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS
TIDE CYCLE OF RECORD STORMS
PROPOSED DESIGN TIDE CYCLE
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.
MINOT'S LEDGE TIDE
APR. 16, 1851
PORTLAND TIDE
NOV. 27, 1898
H.W. 110.4
ESTABLISHED BASIN
ELEV. 108.0
ELEV. 107
PROPOSED DESIGN TIDE CYCLE
HURRICANE CAROL
AUG. 31, 1954
HURRICANE EDNA
SEPT. 11, 1954
MEAN TIDAL CYCLE
HURRICANE DIANE
AUG. 19, 1955
LW
100.7
HOURS BEFORE HIGHTIDE
HOURS AFTER HIGHTIDE
ELEVATION M.D.C. BASE
M.S.L. BASE
115
110
105
6
3
0
3
6
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5

PLATE NO. 11



WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

TIDAL FREQUENCY CURVE

BOSTON HARBOR

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 12

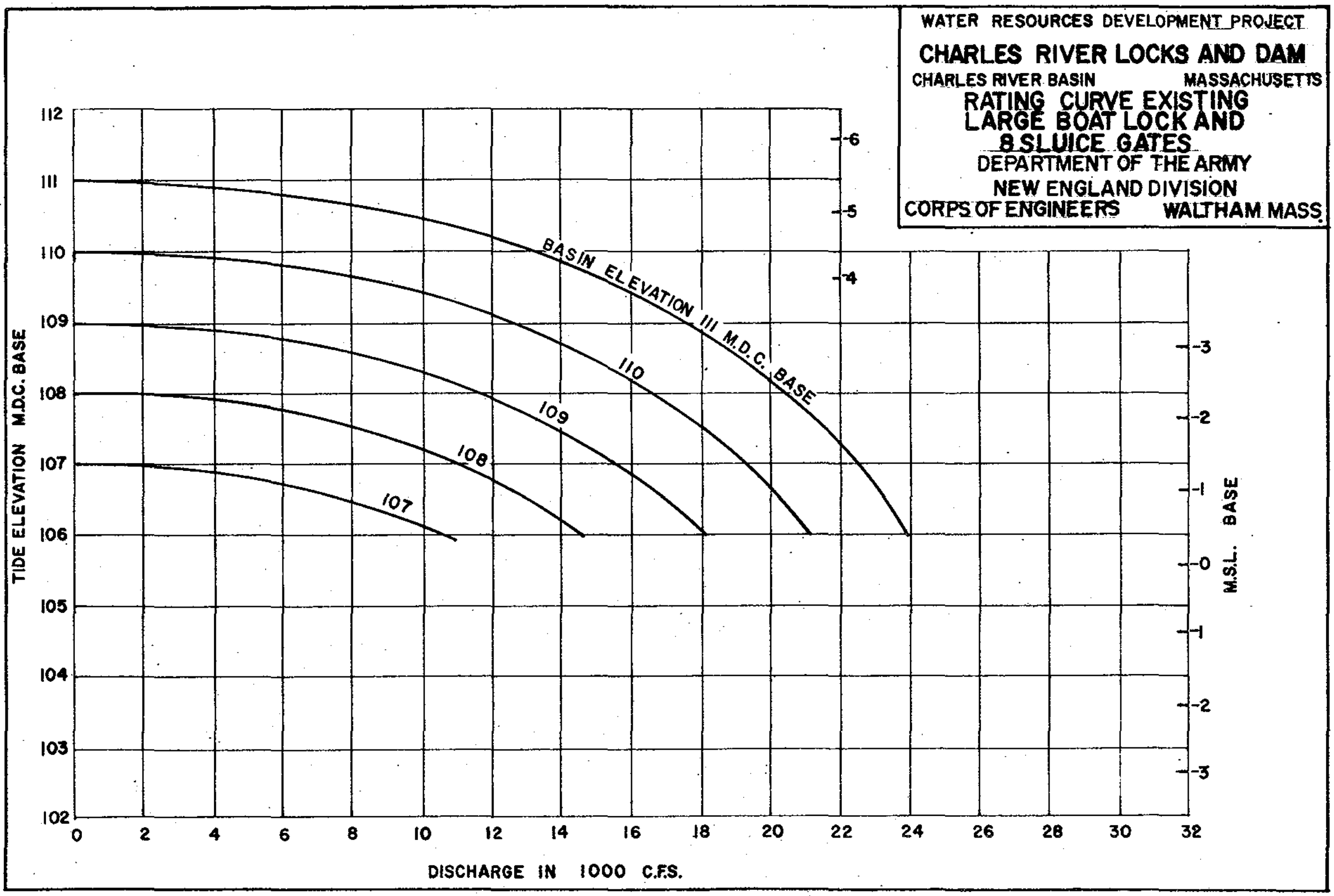
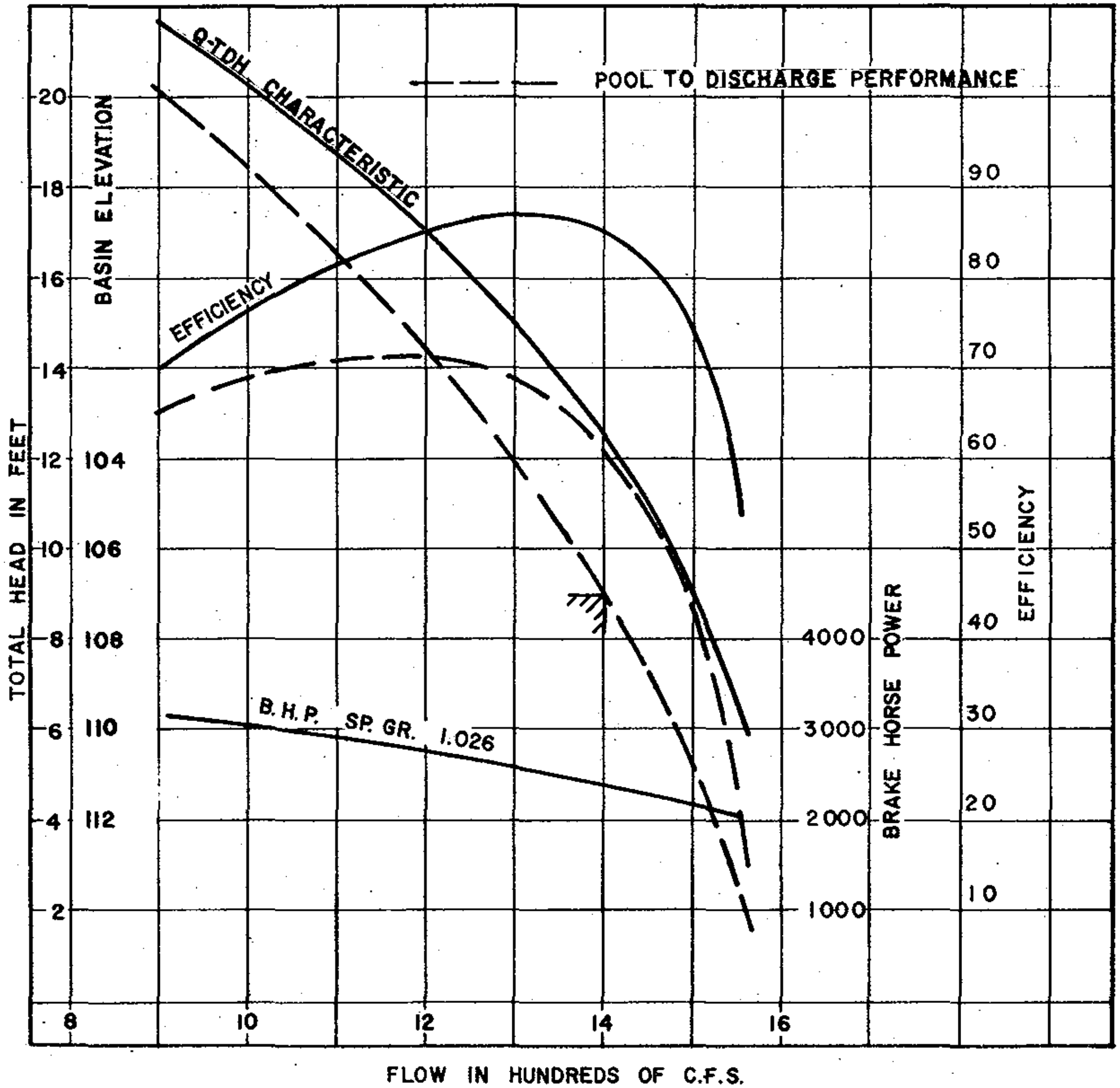

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS
RATING CURVE EXISTING LARGE BOAT LOCK AND 8 SLUICE GATES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM MASS.
TIDE ELEVATION M.D.C. BASE
M.S.L. BASE
DISCHARGE IN 1000 C.F.S.
BASIN ELEVATION 111 M.D.C. BASE
110
109
108
107
112
111
110
109
108
107
106
105
104
103
102
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
6
5
4
3
2
1
0
1
2
3

PLATE NO. 13



DATA FROM MODEL TEST REPORT DATED 3-30-65 DONE UNDER CONTRACT #205-S FOR THE METROPOLITAN DISTRICT COMMISSION BY FAIRBANKS-MORSE

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

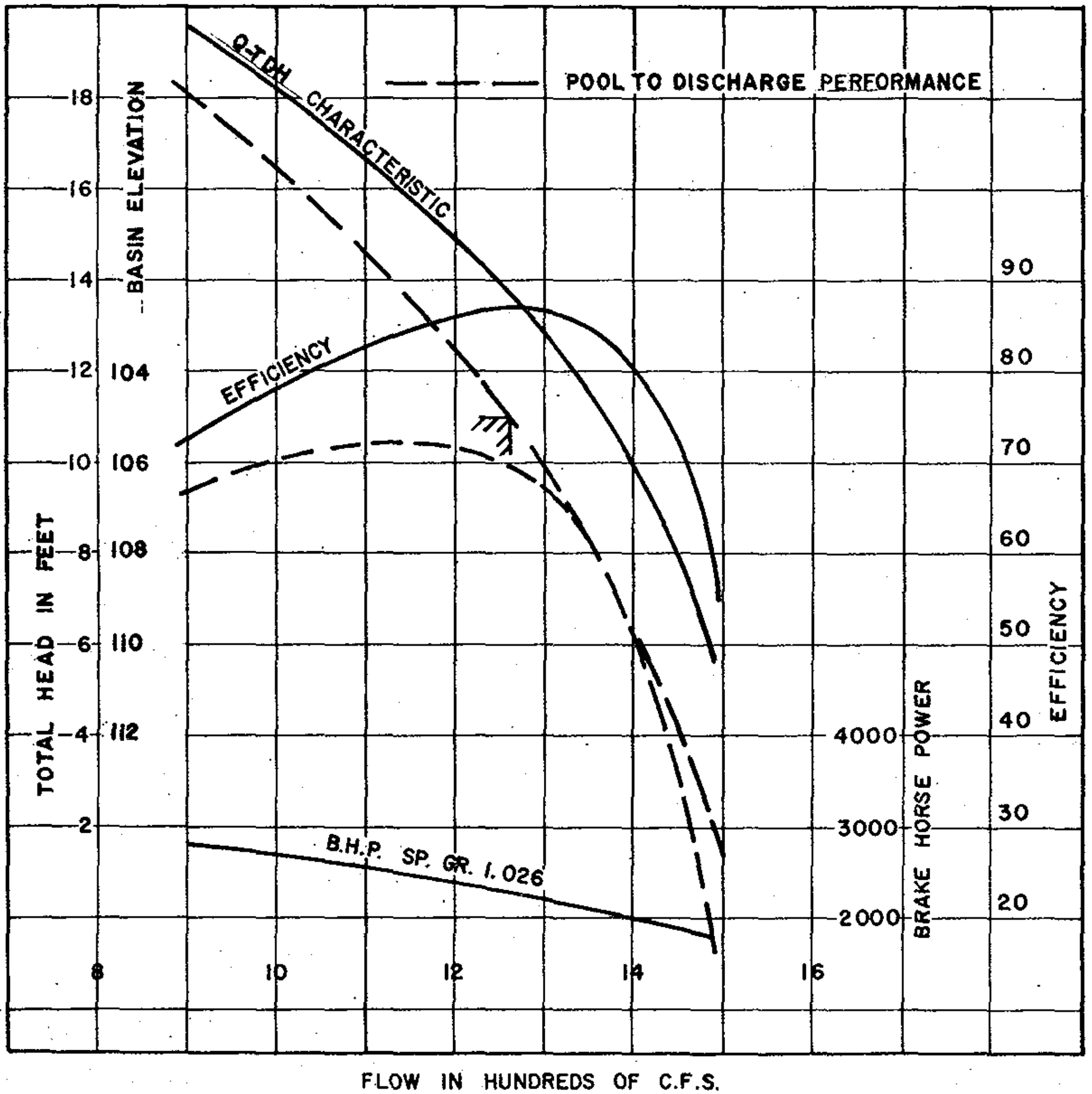
CHARLES RIVER BASIN MASSACHUSETTS

PUMP PERFORMANCE CURVES

144" PUMP AT 105.6 R.P.M.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 14



DATA FROM MODEL TEST REPORT DATED 3-30-65 DONE UNDER CONTRACT #205-S FOR THE METROPOLITAN DISTRICT COMMISSION BY FAIRBANKS-MORSE

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

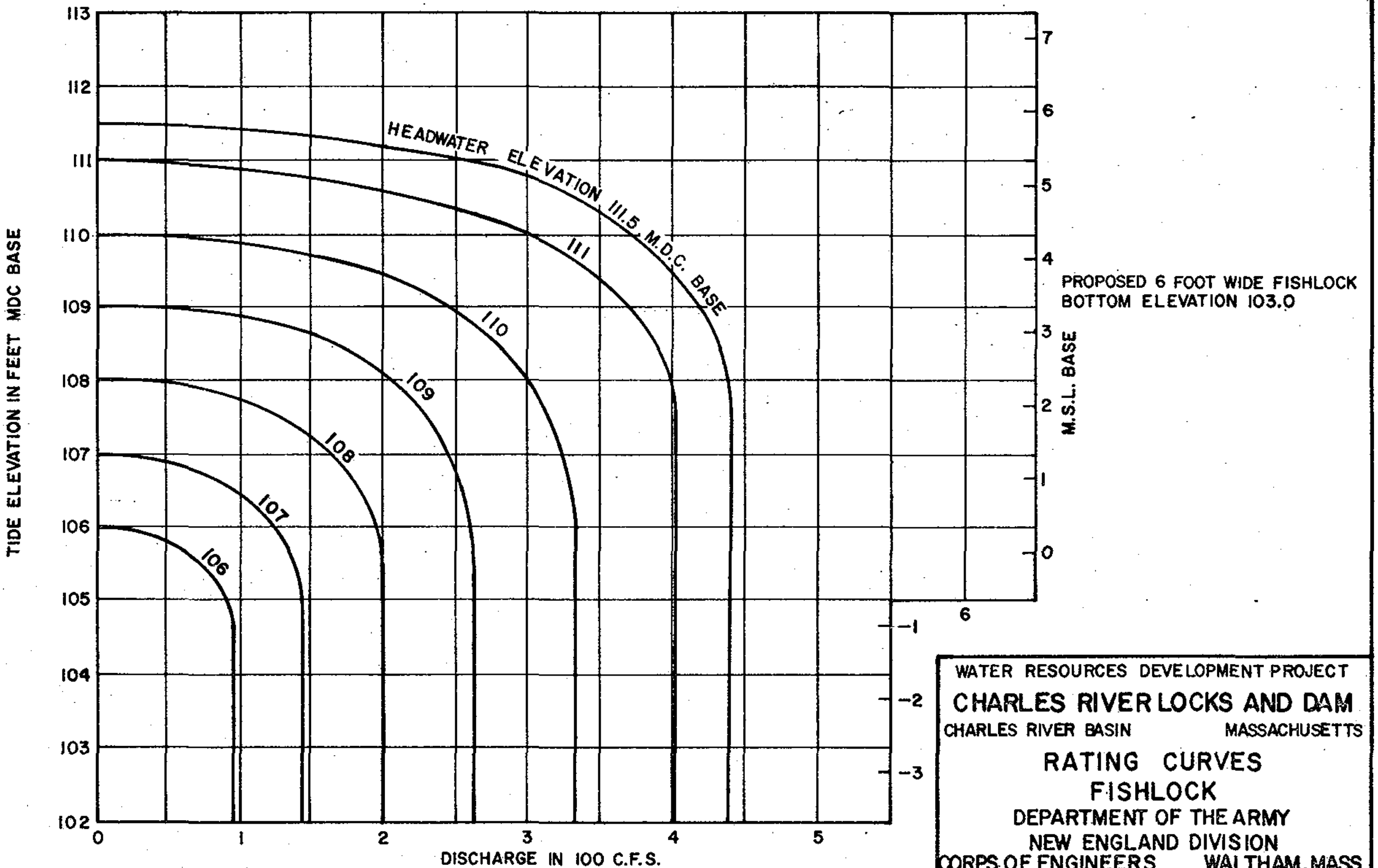
CHARLES RIVER BASIN MASSACHUSETTS

PUMP PERFORMANCE CURVES

144" PUMP AT 101.5 RPM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 15



WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

RATING CURVES

FISHLOCK

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION

CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 16

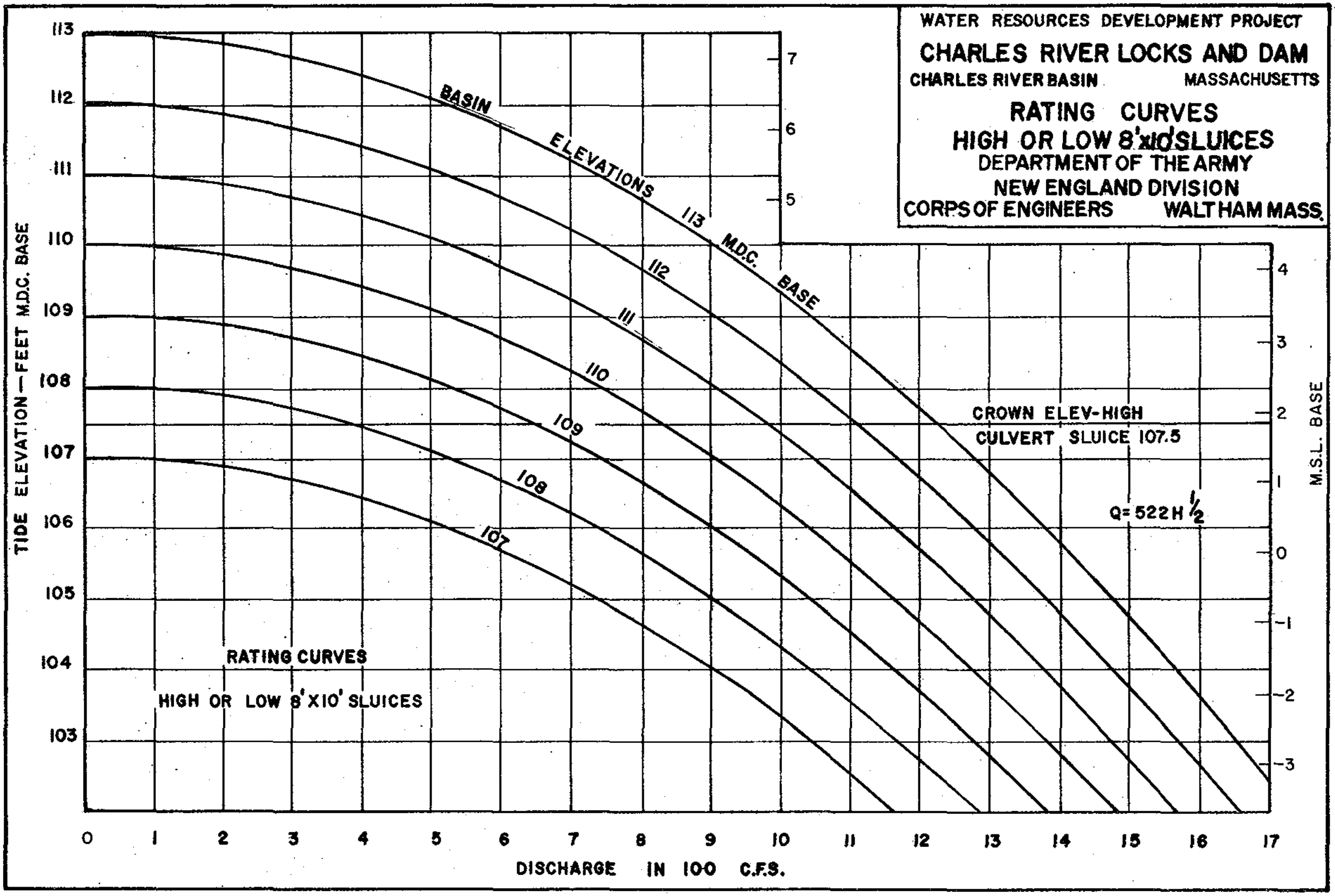
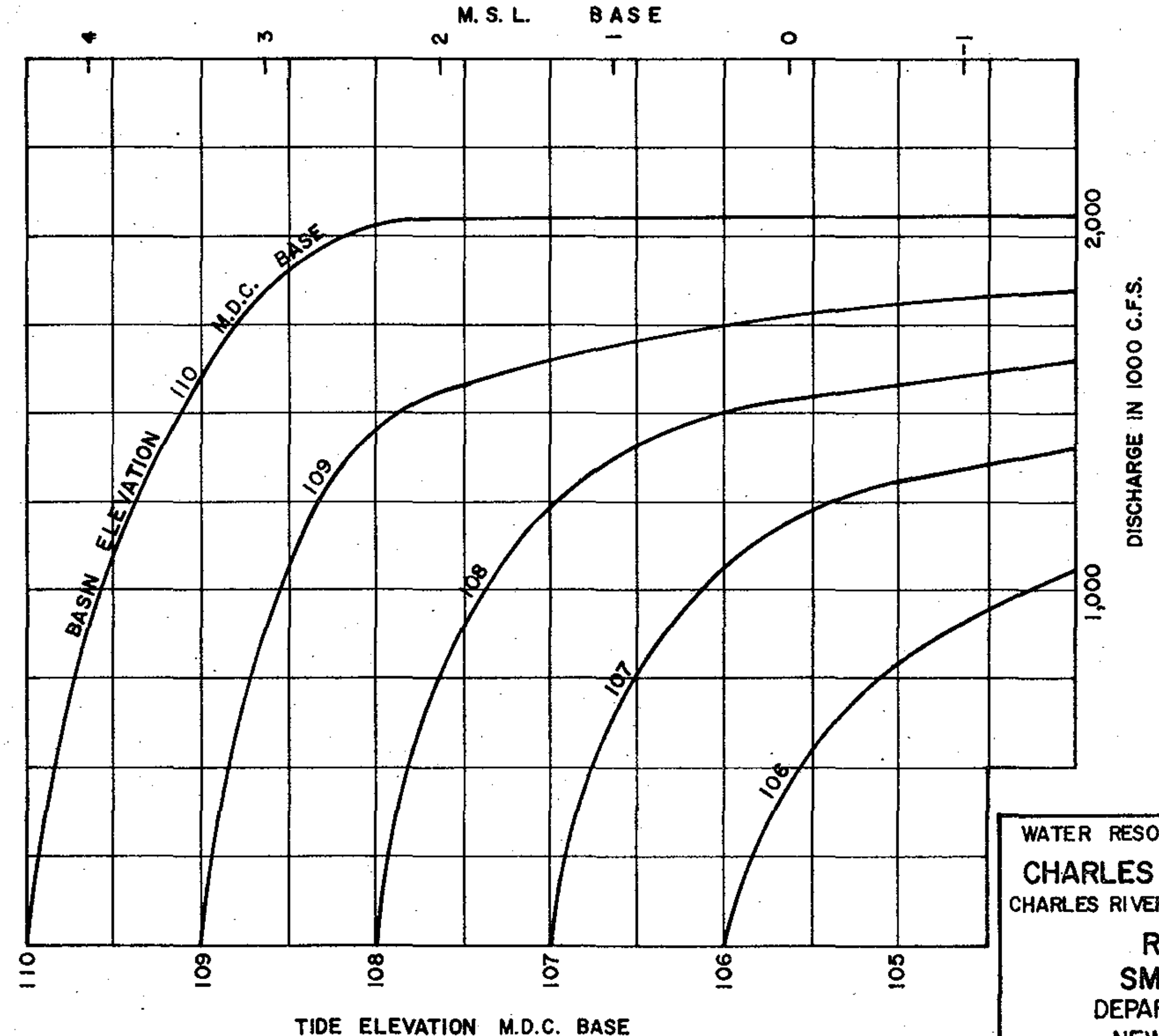

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS
RATING CURVES
HIGH OR LOW 8'x10' SLUICES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM MASS.
BASIN ELEVATIONS 113 M.D.C. BASE
112
111
110
109
108
107
CROWN ELEV-HIGH CULVERT SLUICE 107.5
Q=522H 1/2
RATING CURVES
HIGH OR LOW 8'X10' SLUICES
TIDE ELEVATION—FEET M.D.C. BASE
M.S.L. BASE
DISCHARGE IN 100 C.F.S.

PLATE NO. 17



PROPOSED SMALL BOAT LOCK 25' WIDE.

WATER RESOURCES DEVELOPMENT PROJECT

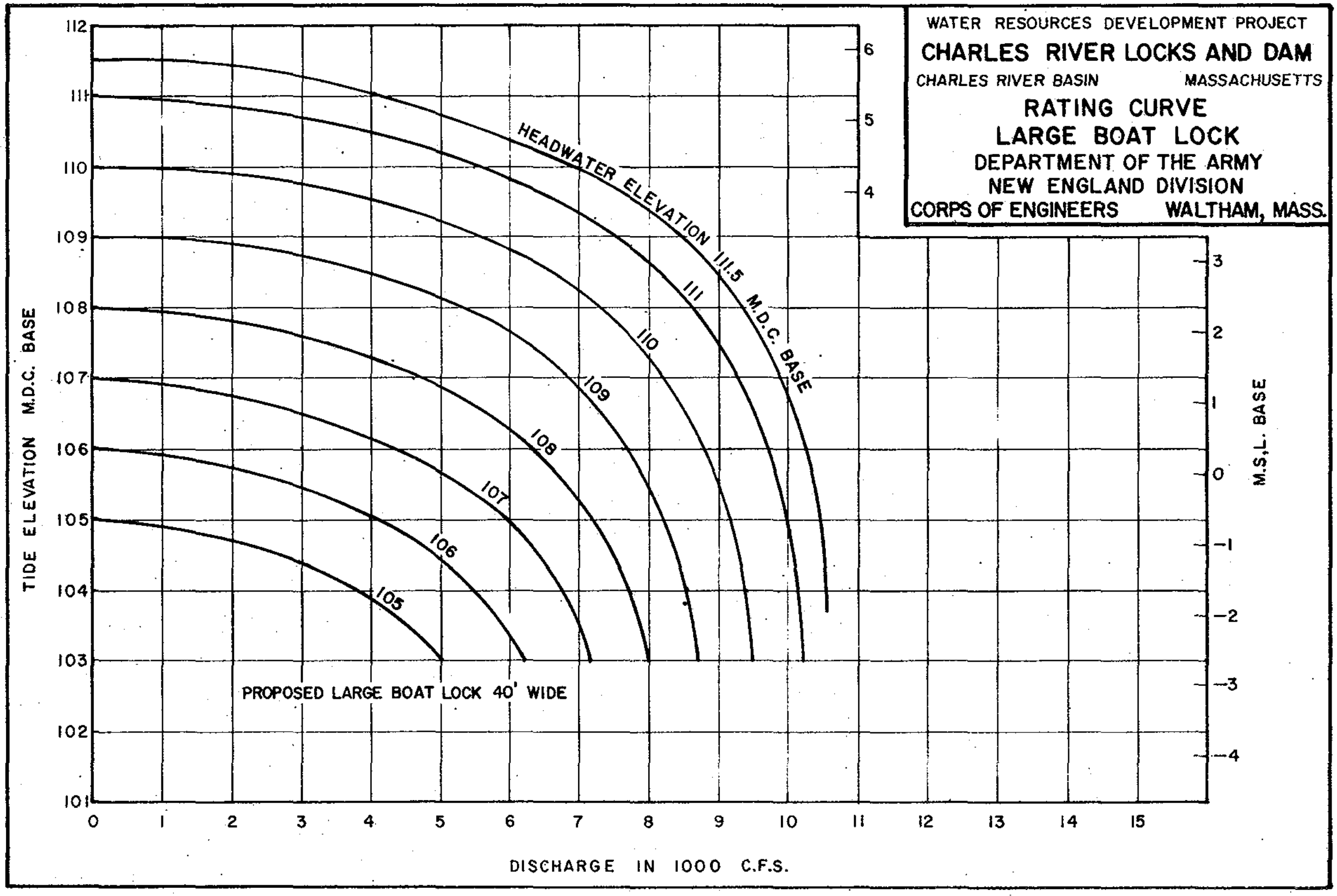
CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

RATING CURVES
SMALL BOAT LOCK

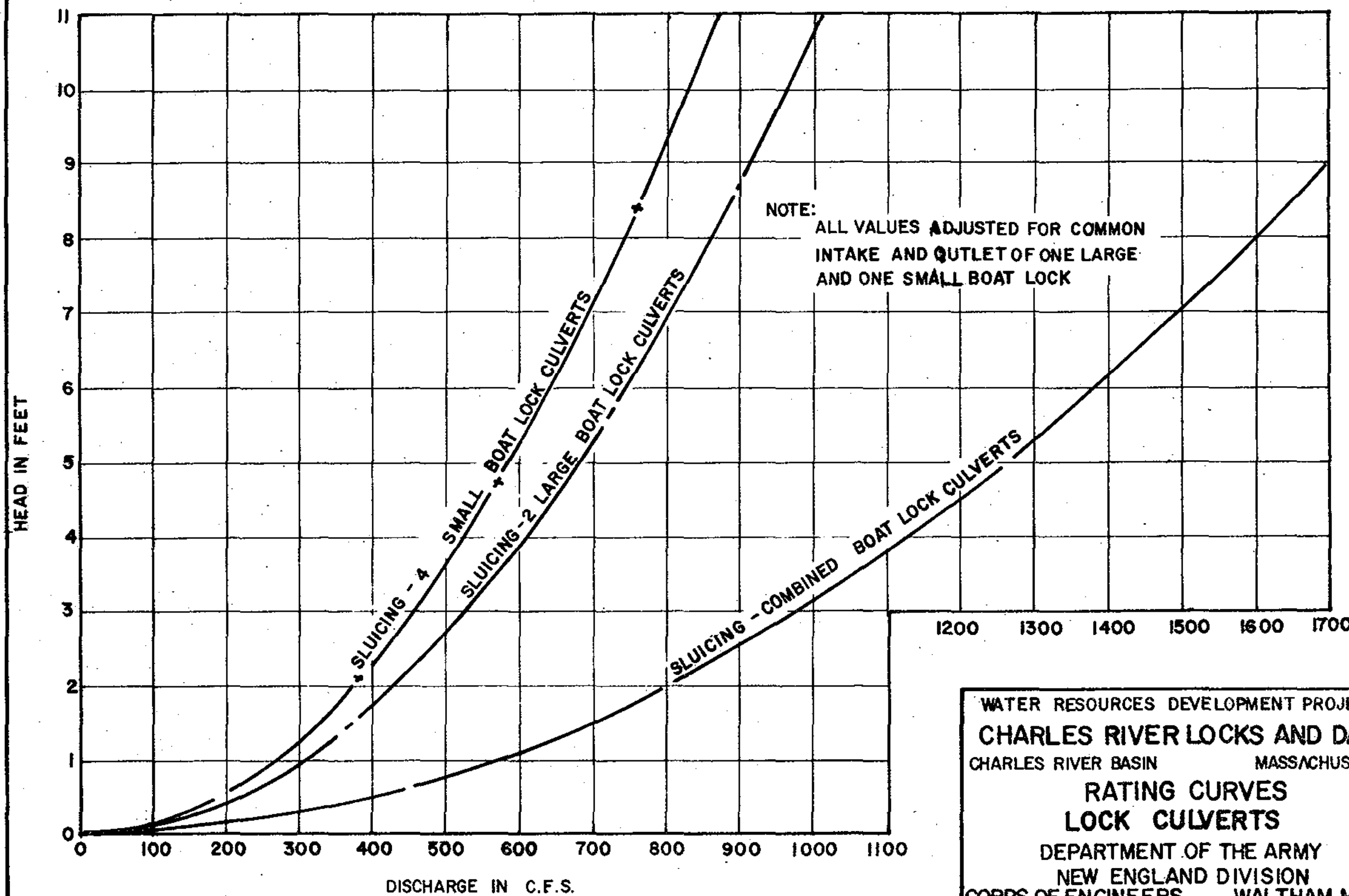
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 18



WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN
MASSACHUSETTS
RATING CURVE
LARGE BOAT LOCK
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
HEADWATER ELEVATION 111.5 M.D.C. BASE
111
110
109
108
107
106
105
PROPOSED LARGE BOAT LOCK 40' WIDE
TIDE ELEVATION M.D.C. BASE
M.S.L. BASE
DISCHARGE IN 1000 C.F.S.

PLATE NO. 19



WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

RATING CURVES
LOCK CULVERTS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 20

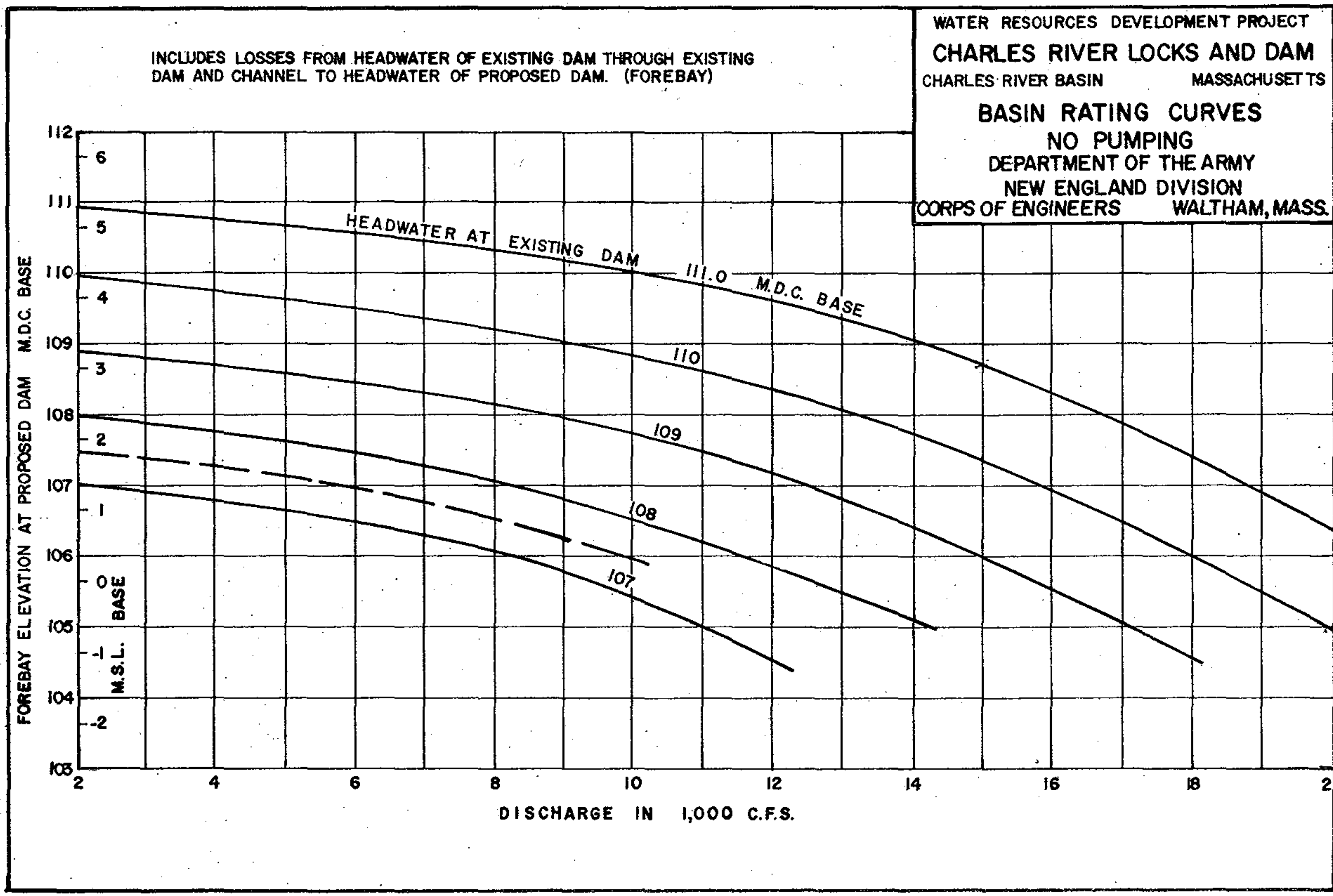
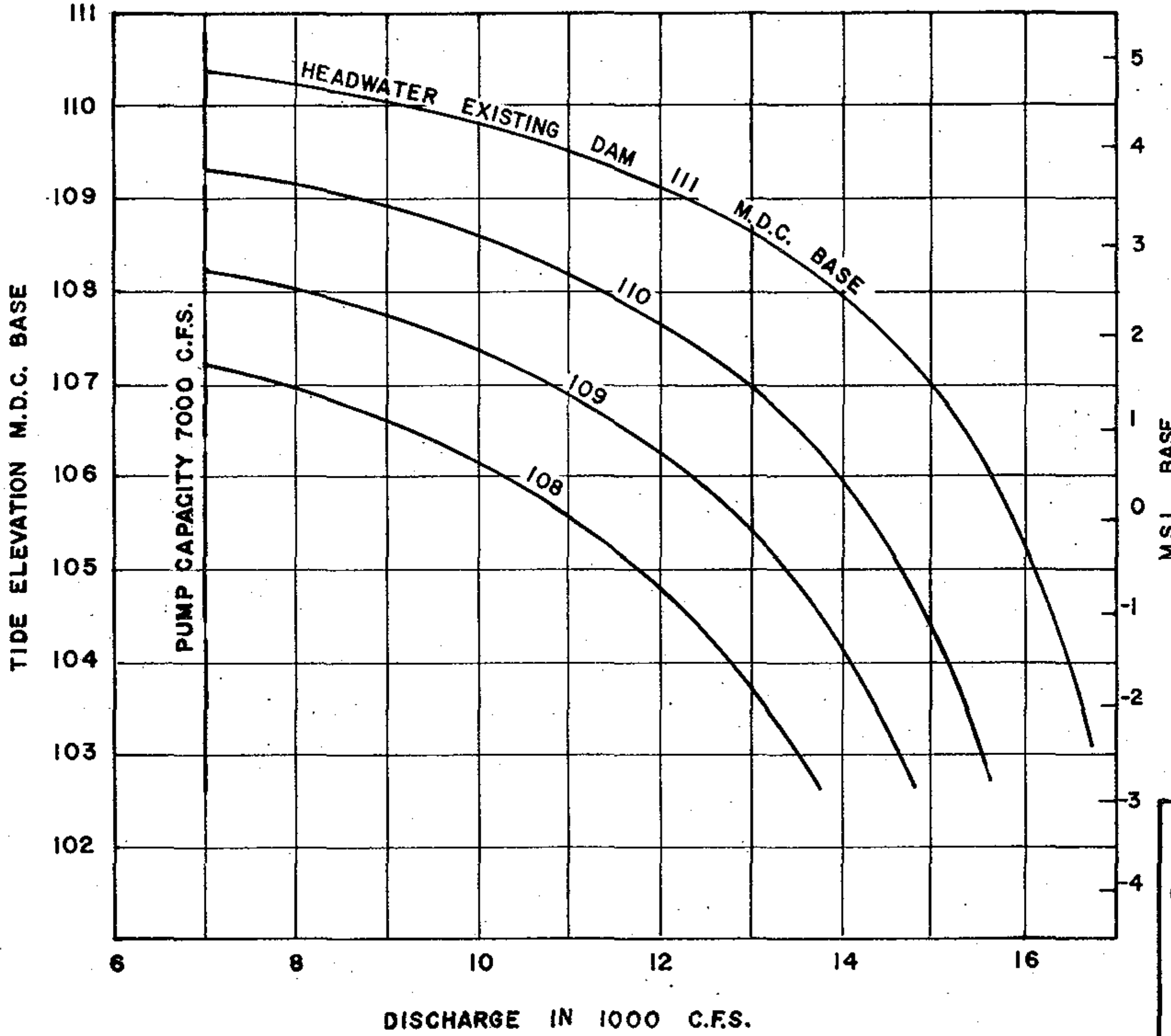

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER LOCKS AND DAM
CHARLES RIVER BASIN MASSACHUSETTS
BASIN RATING CURVES
NO PUMPING
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.
INCLUDES LOSSES FROM HEADWATER OF EXISTING DAM THROUGH EXISTING DAM AND CHANNEL TO HEADWATER OF PROPOSED DAM. (FOREBAY)
HEADWATER AT EXISTING DAM
111.0 M.D.C. BASE
110
109
108
107
FOREBAY ELEVATION AT PROPOSED DAM M.D.C. BASE
M.S.L. BASE
DISCHARGE IN 1,000 C.F.S.

PLATE NO. 21



CONDITIONS

PUMPING AT 7000 C.F.S.

SLUICING - EXISTING DAM

1 - LARGE BOAT LOCK

8 - 7'-6" x 10' SLUICES

SLUICING PROPOSED DAM

1 - LARGE BOAT LOCK

2 - 8' x 10' SLUICES

1 - 6' FISH LOCK

INCLUDES LOSSES FROM HEADWATER OF EXISTING DAM TO TIDE SIDE OF PROPOSED DAM

WATER RESOURCES DEVELOPMENT PROJECT

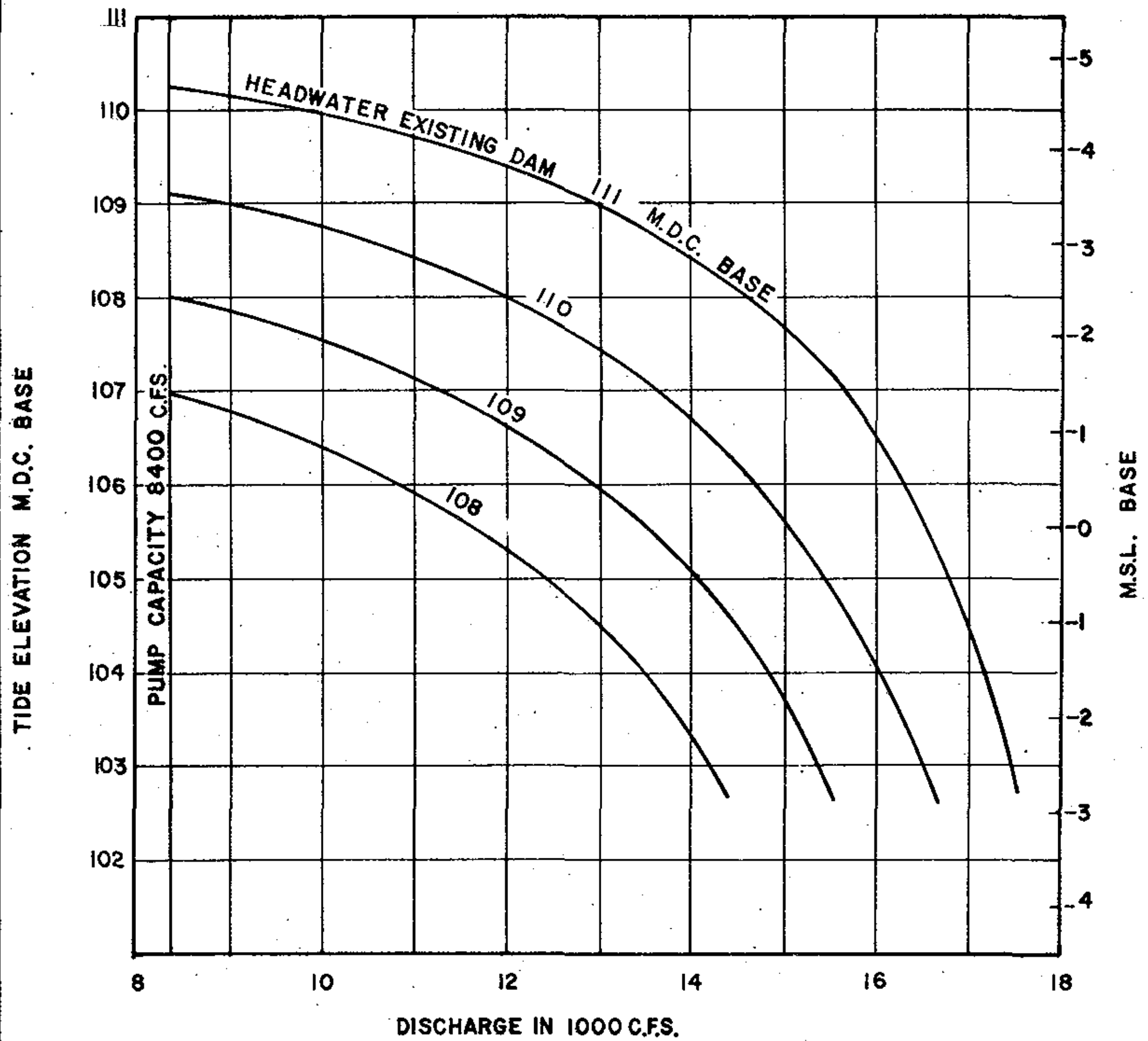
CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

BASIN RATING CURVES PUMPING AT 7000 C.F.S.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 22



CONDITIONS

PUMPING AT 8400 C.F.S.

SLUICING—EXISTING DAM
- 1-LARGE BOAT LOCK
- 8-7'-6" x 10' SLUICES

SLUICING PROPOSED DAM
- 1-LARGE BOAT LOCK
- 2-8' x 10' SLUICES
- 1-6' FISH LOCK

INCLUDES LOSSES FROM HEADWATER OF EXISTING DAM TO TIDE SIDE OF PROPOSED DAM

WATER RESOURCES DEVELOPMENT PROJECT

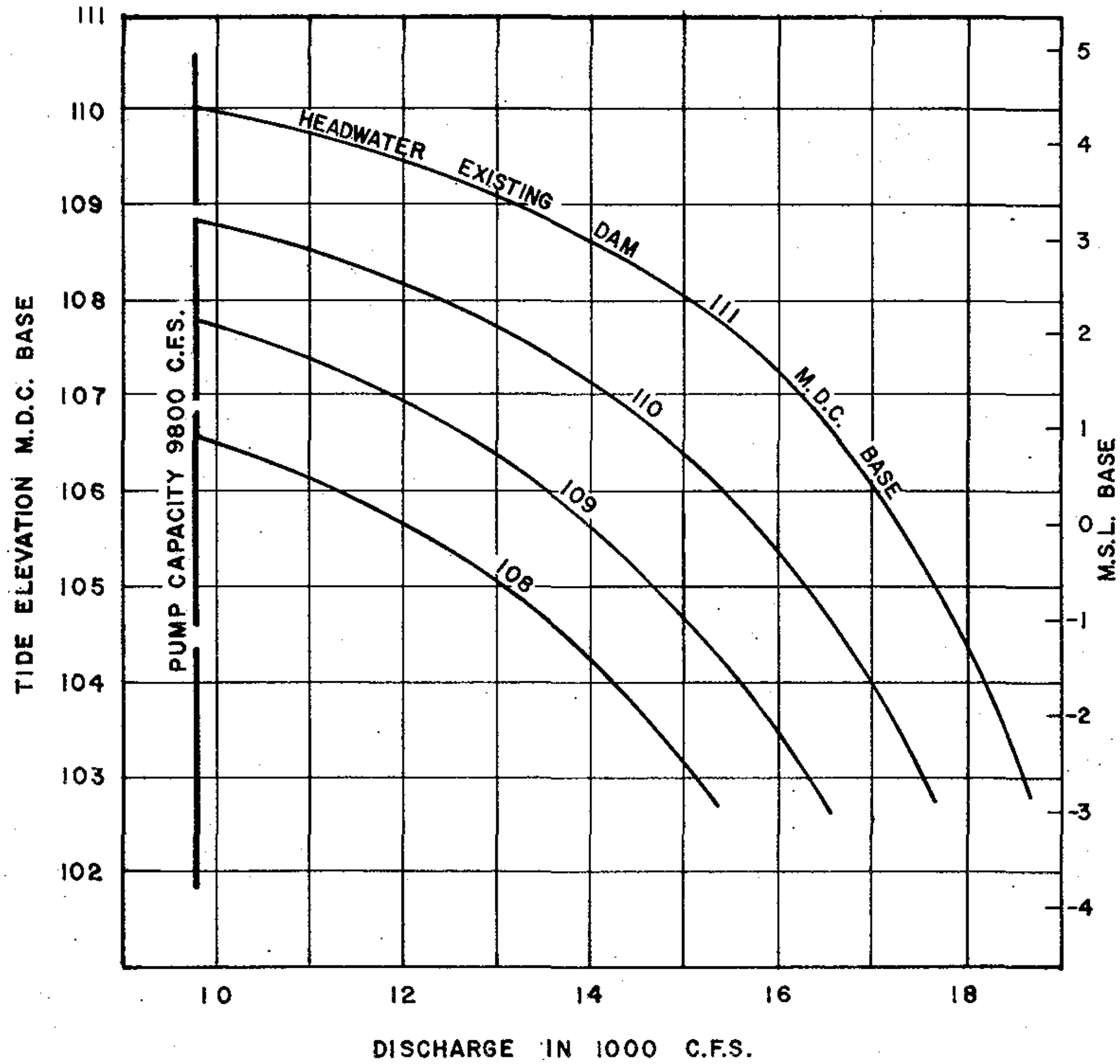
CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

BASIN RATING CURVES
PUMPING AT 8400 C.F.S.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 23



CONDITIONS

PUMPING AT 9800 C.F.S.
SLUICING – EXISTING DAM
1 - LARGE BOAT LOCK
8 - 7'-6" x 10' SLUICES
SLUICING PROPOSED DAM
1 - LARGE BOAT LOCK
2 - 8' x 10' SLUICES
1 - 6' FISH LOCK
INCLUDES LOSSES FROM HEADWATER OF EXISTING DAM TO TIDE SIDE OF PROPOSED DAM

WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER LOCKS AND DAM

CHARLES RIVER BASIN MASSACHUSETTS

BASIN RATING CURVES
PUMPING AT 9,800 C.F.S.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS WALTHAM, MASS.

PLATE NO. 24